FINAL DRAFT REPORT

EVERGLADES PROTECTION PROJECT

Contract C-3051, Amendment 4

PHASE II EVALUATION OF ALTERNATIVE TREATMENT TECHNOLOGIES

Submitted to:

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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EXECUTIVE SUMMARY

Background

The South Florida Water Management District (District), in its adoption of the Surface Water Improvement and Management (SWIM) Plan for the Everglades Agricultural Area (EAA) committed to evaluate alternative technologies to the recommended treatment system utilizing Stormwater Treatment Areas (STAs). Brown and Caldwell, under Contract C-3051, "Evaluation of Alternative Technologies, Everglades Protection Project," has been systematically evaluating the numerous alternative technologies to determine whether any of these technologies have the potential to be more effective, both from a technological and economical standpoint, to the current SWIM Plan. The current SWIM Plan proposes a combination of STAs and reduced phosphorus discharges from agricultural lands in the EAA through on-farm best management practices (BMPs).

The scope of the evaluations completed and currently in progress by Brown and Caldwell includes a review of the proposed BMPs for three farm crops--sod, sugarcane, and vegetables--and the alternative technologies applied at various scales of application. The output of this effort will provide the District with a solid technical basis on which to modify the current SWIM Plan if either the BMP or alternative technology evaluation provides information that warrants a change in the Plan. The key element of these evaluations is to provide a common basis for analysis for both the BMPs and alternative technologies so decisions regarding selection of the ultimate Plan can be made utilizing defensible evaluation tools. In these evaluations, capital and operating costs for each technically viable BMP and alternative technology have been estimated and used to develop a unit cost-per-pound of phosphorus removed. This information will be critical during the Plan Formulation Phase of the Everglades Protection Project in evaluating the numerous combinations of technologies and BMPs for inclusion in a plan that is workable, defensible, and cost-effective and meets the objectives of the Everglades Protection Project.

Prior Work

This report, prepared under Amendment No. 4 to Contract C-3051, is the third in a series of reports related to the evaluation of alternative treatment technologies. The first report, prepared under Amendment No. 1, involved the development of criteria to evaluate the various technologies. The second report, prepared under Amendment No. 2, involved the initial screening of the various treatment technologies that had been proposed to the District for consideration.

To put this report in proper perspective, it is important to review the scope of the screening evaluation that was the focus of the Amendment No. 2 report. The Amendment No. 2 report evaluated 16 treatment technologies proposed by various individuals, consultants, and special-interest groups. A number of these technologies were included in the presentation made by the Florida Sugarcane League (FSCL) to the District Governing Board at the April 1992 regular meeting. These 16 technologies were evaluated at four scales of application: (1) basin scale, comparable to the current STA conceptual design; (2) sub-basin scale, established at 10 percent the size, flow volume and phosphorus loading of the basin scale; (3) farm scale; and (4) point source scale. Recognizing that a range of effectiveness in removing phosphorus exists for several of the technologies, each technology was evaluated for three levels of phosphorus reduction--25, 50, and 75 percent--at the four scales of application described above. This evaluation provided a general assessment of the effectiveness of the technology over a very broad range of applications and phosphorus reduction goals. The screening criteria that were used to eliminate less promising technologies included nine individual criteria, with each criterion assigned a weighting factor based on the relative importance of the criterion to meeting the goals of the SWIM Plan. Effectiveness in removing phosphorus was the highest weighted criterion. Order-of-magnitude capital cost estimates were prepared but were not assigned a high criterion weighting.

From this screening evaluation, two technologies--STAs (or wetlands) and chemical treatment followed by a wetland--were the top rated technologies for all four scales of application. Direct filtration was one of the three top rated alternatives for the basin and sub-basin scale. Chemical treatment was an additional top rated technology for the farm scale. Deep well injection and percolation ponds were top rated technologies for point source applications.

In general, the screening analyses indicated that treatment at the sub-basin scale would not provide an advantage over the basin scale with regard to effectiveness or cost, and was dropped from further evaluation. Other changes in the approach included focusing the Amendment No. 4 work on evaluating the top rated alternative technologies at the optimum phosphorus reduction range and eliminating the evaluation of technologies at alternative phosphorus reduction levels. Calculation of cost per unit of phosphorus removed was added to the evaluation process to allow alternative technologies to be compared even though the phosphorus removal percentages may be different.

<u>Scope of Amendment No. 4 Evaluation</u>

Using the results of the Amendment No. 2 work, the emphasis in this report was to evaluate seven specific waste streams typical of those found in the EAA. The seven waste streams evaluated were:

1. <u>Basin S-5A</u>. This basin was selected due to the high phosphorus concentration measured over the period of record, 1979 to 1988.

2. <u>Basin S-7</u>. This basin was selected due to the relatively low phosphorus concentration measured over the period of record. The phosphorus concentration was approximately one-half that of Basin S-5A for the period of record. The remaining two basins were not evaluated, because the phosphorus concentrations measured in Basin S-6 and S-8 were between the two selected basins.

3. <u>Model Sugarcane Farm</u>. To evaluate farm treatment technologies, a 6400-acre "typical" sugarcane farm was developed. Treatment technologies applied to a farm discharge are

distinguished from a BMP in that the treatment technologies are applied only at the discharge point from the farm and do not involve any changes in farm practices, such as water management or fertilization.

4. Model Vegetable Farm. Like the model sugarcane farm, a 1200-acre "typical" vegetable farm was developed to evaluate the effectiveness of the selected treatment technologies in reducing phosphorus loads from the farm discharge.

5. Sugar Mill Discharge. Even though most of the sugar mills use percolation ponds and have limited or no direct discharge to the surface waters in the EAA, there is evidence that the wastewater treatment systems for the sugar mills may be contributing significant phosphorus loads to the EAA. With the relatively high phosphorus concentration and low volumes of water discharged, these discharges also vary significantly from the other six selected discharges.

6. Small Package Treatment Plants. Numerous small wastewater treatment plants are located in the EAA and primarily serve labor camps. The effluent from the a package treatment plant typically has phosphorus concentrations on the order of 2 to 7 mg/l. Technologies were evaluated to reduce the level of phosphorus in the discharge to a level consistent with advanced wastewater treatment.

7. Municipal Wastewater Treatment Plants. The four major municipal wastewater treatment plants in the EAA basin have historically contributed phosphorus to the basin. An evaluation of the proposed effluent disposal practices for each facility was made to determine whether additional phosphorus reduction measures would be necessary to reduce the contributions from these sources.

For these seven discharges, the following treatment technologies were evaluated:

Basin S-5A
1. Stormwater treatment areas (STAs)
2. Direct filtration
3. Chemical treatment using sedimentation basins followed by a wetland treatment system

Basin S-7
1. Stormwater treatment areas (STAs)
2. Direct filtration
3. Chemical treatment using sedimentation basins

Model Sugarcane and Vegetable Farms
1. Farm treatment areas (farm scale STAs)
2. Chemical treatment using sedimentation basins
3. Chemical treatment using modified canal sections

Sugar Mill
1. Percolation ponds
2. Chemical treatment using sedimentation basins
3. Deep well injection
4. Wetlands

Municipal and Small Package Treatment Plants
1. Chemical treatment applied to existing treatment units
2. Wetland
3. Direct filtration

Three different levels of effort were applied to the evaluation of alternative treatment technologies for the seven model discharges. Factors influencing the level of effort devoted to each evaluation included (1) the relative magnitude of the phosphorus load involved, (2) the results of the Amendment No. 2 screening evaluation, and (3) guidance from the District regarding the waste streams and technologies that would most likely be carried through Plan Formulation, and therefore, should be given priority in this evaluation. The three levels of evaluation performed were as follows:

1. Full application of the Phase II Evaluation criteria as developed and described in the Amendment No. 1 Report entitled, Evaluation Methods and Procedures, September 25, 1992, prepared by Brown and Caldwell.

2. Development of a detailed economic evaluation including capital, operation and maintenance, and present-worth costs to supplement an overall evaluation of the relative effectiveness of each technology in achieving the selected phosphorus removal goals.

3. Development of a noneconomic evaluation of the appropriateness of selected technologies to satisfy phosphorus goals.

For the basin scale evaluations, the Phase II Evaluation criteria were used to rank the three technologies, both on economic and noneconomic considerations. The farm scale alternative technologies were evaluated using the second level of evaluation which focused primarily on effectiveness and cost considerations. The sugar mill and wastewater treatment plants were evaluated qualitatively using the third level of evaluation. For these point source discharges, cost estimates were not developed as these discharges would be regulated through the FDER and EPA discharge permitting processes. If these discharges are considered to be significant contributors to the EAA, then individual evaluations of each point source would be appropriate to determine the cost-effectiveness of the identified technologies for that discharge.

BASIN SCALE ALTERNATIVE TREATMENT TECHNOLOGIES

For the evaluation of alternative treatment technologies at the basin scale (i.e., alternatives that treat water from one of the four large basins that make up the EAA), data furnished by the District were compiled over the 9.75-year period of record from 1979 through 1988 for Basins S-5A and S-7. After taking into account through-basin flow to and from Lake Okeechobee and assuming implementation of proposed BMPs to achieve 20 percent flow and 25 percent P reduction, P concentrations in agricultural drainage water from Basins S-5A and S-7 were determined to be 0.187 and 0.094 mg/l, respectively. The objective is to reduce the P concentration to 0.05 mg/l before discharge to the downstream Water Conservation Areas.

The two alternative treatment technologies that use chemical treatment processes can reduce the P concentration to less than 0.05 mg/l. This is an advantage because all basin flow does not have to be treated, as is the case with the STAs. A portion of the basin flow bypasses the treatment facilities and blends with the treated waters to achieve the final P concentration objective of 0.05 mg/l. The methodology used to determine the portion of basin flow that must be treated is presented in Chapter 2. This process determines the required flow capacity of the treatment plants. The key to the success of these treatment technologies is the ability of the direct filtration system to reduce phosphorus levels to 0.01 mg/l, or one fifth of the target level (0.05 mg/l), and for the chemical treatment system to reduce phosphorus to 0.04 mg/l.

Using the period of record flows and phosphorus loading, an analysis was performed on the chemical treatment and direct filtration systems to determine the number of basin flowdays in S-5A and S-7 below the design capacity of the treatment systems. For Basin S-5A, the direct filtration system will treat <u>all</u> flows to the 0.01 mg/l phosphorus level on 74 percent of the flowdays, and for Basin S-7, the system will treat all flows on 56 percent of the flowdays. For chemical treatment, all the flow is treated for 61 percent of the flowdays in both Basin S-5A and Basin S-7.

Descriptions of the alternative basin scale treatment technologies are presented below.

<u>Direct Filtration</u>

Direct filtration is a water treatment process consisting of chemical precipitation and solids destabilization in a rapid mixer, flocculation in basins to develop readily-filtered chemical floc, and gravity flow through multi-media filters to remove the floc and bound-up solids. Chemical reactions during the rapid-mix and flocculation process convert much of the soluble P into particulate P which gets bound up in the floc. The floc is then removed in the filters. The filters are periodically backwashed to remove the solids from the filter media. The removed solids become sludge that is thickened by gravity in an earthen basin before disposal on land dedicated for that purpose.

At present, it does not appear that sludge produced in the direct filtration process will be regulated because it is produced as a result of treating agricultural drainage waters and contains no human wastes. Should further study reveal that unacceptable environmental impacts result from either heavy metal buildup over time or potential impacts on groundwater resources, mechanical sludge dewatering followed by disposal in on-site lined landfills equipped with leachate monitoring and collection systems could be substituted for dedicated land disposal.

The chemicals considered for use as the primary coagulant include iron salts (primarily ferric chloride), aluminum sulfate (alum), and lime. The chemical reactions and advantages and disadvantages of the alternative coagulants are discussed in Chapter 2. Ferric chloride has been tentatively selected for its ability to achieve P reduction goals, low cost, and availability (although alum deserves further consideration). Other chemicals which may be used in the treatment process include pH-adjustment chemicals and polymers as coagulation and filtration aids.

Much of the work on the conceptual design of direct filtration was based on recent experience at the Wahnbach Reservoir Plant near Bonn, Germany. This plant treats agricultural drainage water with direct filtration to reduce P concentrations from about 0.25 to 0.004 mg/l. The similarities between the Wahnbach plant and the direct filtration system evaluated for the EAA basins are striking. The maximum filtration rate at the Wahnbach plant is 6 gpm/sq ft, but recent experience treating combined domestic wastewater and stormwater suggest that higher filtration rates are feasible. Therefore, low rate direct filtration plants using maximum filter rates of 6 gpm/sq ft and high rate direct filtration plants using maximum filtration rates of 11 gpm/sq ft were both evaluated. The maximum filter rates attainable in EAA direct filtration plants will probably fall somewhere in this range. Pilot plant testing of actual EAA waters must be accomplished to determine the correct filtration rate with confidence.

A treatment process flowsheet for direct filtration is shown on Figure ES-1. The basis of design for direct filtration is presented in Table ES-1. A site layout for high-rate (11 gpm/sq ft) direct filtration at Basin S-5A is shown on Figure ES-2; similar site layouts for the other direct filtration alternatives appear in Chapter 2. The estimated capital, annual operation and maintenance (O&M), present-worth costs, and cost per pound of P removed are presented in Table ES-2 for Basin S-5A and S-7. High-rate filtration has the potential to reduce costs substantially, as shown in Table ES-2.

The land area required for the direct filtration alternatives is much less than the area required for STAs. The land required for direct filtration at Basin S-5A is 424 acres compared with 12,200 acres for the STA as developed in the March 1992 conceptual design report prepared by Burns & McDonnell. The land required for direct filtration in Basin S-7 is 186 acres compared with 6,220 acres for the STA.

The schedule for the planning, permitting and design of the direct filtration systems for the two basins is based upon beginning bench scale testing in April 1993 and pilot testing in July 1993. By beginning pilot testing in July, six months of pilot operating data can be developed prior to the scheduled initiation of detailed design in January 1994. Actual construction of the

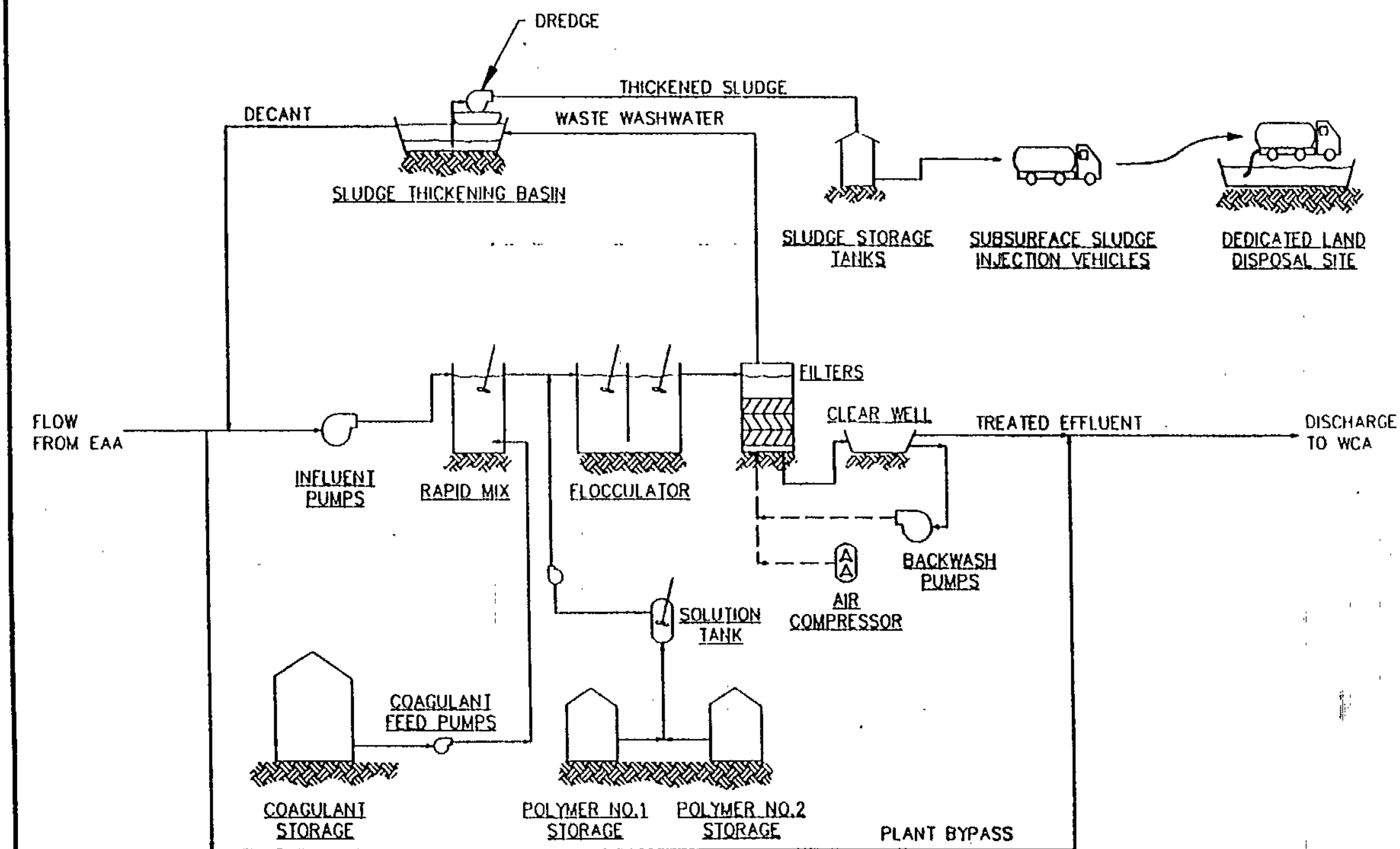

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FIGURE ES-1.
DIRECT FILTRATION FLOWSHEET

E:/7138/FIGES-1

Table ES-1 Basis of Design for Direct Filtration

Item	Basin S-5A	Basin S-7
Basin data		
Flow, million gals		
Maximum annual	95,565	105,913
Minimum annual	41,627	28,817
Average annual	70,134	76,819
P concentration, mg/L		
Maximum annual	0.234	0.140
Minimum annual	0.121	0.056
Average	0.187	0.094
TSS concentration, mg/L		
50th percentile	19	6
90th percentile	40	14
95th percentile	58	16
Plant data		
Percent of days on line	33	71
Flow, mgd		
Maximum	835	220
Minimum	0	0
Average		
All days	148	110
When operating	451	155
Maximum year		
Average all days	192	151
When operating	584	213
Influent pumps		
Number of small pumps	1	1
Capacity each small pump, gpm	30,000	30,000
Peak plant flow, mgd	835	220
Number of large pumps	5	3
Capacity each large pump, gpm	138,000	62,000

Table ES-1 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33 percent $FeCl_3$	Liquid, 33 percent $FeCl_3$
Dose, as Fe, mg/L		
Average	5.7	5.7
Maximum	10	10
Pumps		
Number (1 spare)	5	2
Capacity, each, gpm	10	10
Storage tank		
Volume, gals	740,000	195,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2
Polymer No. 1		
Form	Liquid, slightly cationic	Liquid, slightly cationic
Dose, mg/L		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	5	2
Capacity, each, gpm	1.4	1.5
Solution tank volume, gals	10,000	2,600
Storage tank		
Volume, gals	2,500	600
Storage at peak feed rates, wks	2	2
Polymer No. 2		
Form	Liquid, slightly cationic	Liquid, slightly cationic
Dose, mg/L		
Average	0.5	0.5
Maximum	1.0	1.0
Pumps		
Number (1 spare)	5	2
Capacity, each, gpm	7.0	7.4
Solution tank volume, gals	50,000	13,000
Storage tank		
Volume, gals	11,000	3,000
Storage at peak feed rates, wks	2	2

Table ES-1 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Rapid mix tanks		
Number, in parallel	4	1
Volume, each, gals	4,800	5,100
Detention time at peak plant flow, sec	2	2
Velocity gradient, sec^{-1}	750	750
Power input per tank, HP	20	20
Material of construction	Concrete	Concrete
Flocculators		
Number, in parallel	4	1
Stages per flocculator	2	2
Volume per stage, gal	218,000	229,000
Detention time per stage at peak flow, mins	1.5	1.5
Velocity gradient, sec^{-1}		
Maximum	50	50
Minimum	110	110
Power input per tank, HP	20	20
Material of construction	Concrete	Concrete
Filters (low rate)		
Number, in parallel	80	20
Surface area per bed, ft^2	1,385	1,379
Material of construction	Concrete	Concrete
Width x length, ft	24 x 58	24 x 57
Filter rate, gpm/ft^2		
Maximum	6	6
Average, when operating	2.8	3.9
Solids load, $lb/day.ft^2$		
Maximum	4.5	2.0
Average, when operating	1.0	0.9
Filters (high rate)		
Number, in parallel	48	12
Surface area per filter, ft^2	1,324	1,303
Material of construction	Concrete	Concrete
Width x length, ft	24 x 55	24 x 54
Filter rate, gpm/ft^2		
Maximum	11	11
Average, when operating	4.7	6.9
Solids load, $lb/day.ft^2$		
Maximum	7.8	3.6
Average, when operating	1.9	1.6

Table ES-1 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Filter Media		
Top layer		
Material	Activated carbon	Activated carbon
Effective size, mm	3.3	3.3
Uniformity coefficient	1.46	1.46
Depth, in	14	14
Middle layer		
Material	Anthracite	Anthracite
Effective size, mm	1.73	1.73
Uniformity coefficient	1.32	1.32
Depth, in	57	57
Bottom layer		
Material	Quartz sand	Quartz sand
Effective size, mm	0.87	0.87
Uniformity coefficient	1.28	1.28
Depth, in	24	24
Available headloss increase, ft	7	7
Method of flow control	Rate of flow control valve	Rate of flow control valve
Underdrain	Block	Block
Backwash system		
Backwash reservoir (clear well)		
Number, in parallel	1	1
Volume, each, gals	250,000	250,000
Depth, ft	10	10
Surface area, acres	0.08	0.08
Material of construction	Concrete	Concrete
Backwash		
Maximum rate, gpm/ft^2	31	31
Number of pumps	12	4
Capacity, each, gpm	23,000	23,000
Air Scour		
Rate, $scfm/ft^2$	4	4
Number of compressors	4	1
Capacity, each, scfm	5,200	5,200

Table ES-1 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Washwater reclamation basin/thickener		
Volume, million gals	57	27
Depth, ft	15	15
Surface area, acres	11.7	5.5
Reclaimed washwater pumps		
Number (1 spare)	5	2
Capacity, each, gpm	6,300	6,300
Number of dredges	1	1
Capacity each dredge, gpm	1,000	500
Concentration of dredged sludge, percent	5	5
Material of construction	Earth	Earth
Dedicated land disposal		
Sludge production, tons dry solids per year		
Maximum	9,537	4,539
Average	7,357	3,306
Maximum application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	7	3
Area per section, acres	48	53
Number of sludge storage tanks	7	3
Volume each sludge storage tank, gals	7,500	7,500
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	2	1
Spreading capacity each, gal/day	120,000	120,000
Land requirements, acres		
Low-rate filters	424	186
High-rate filters	423	185

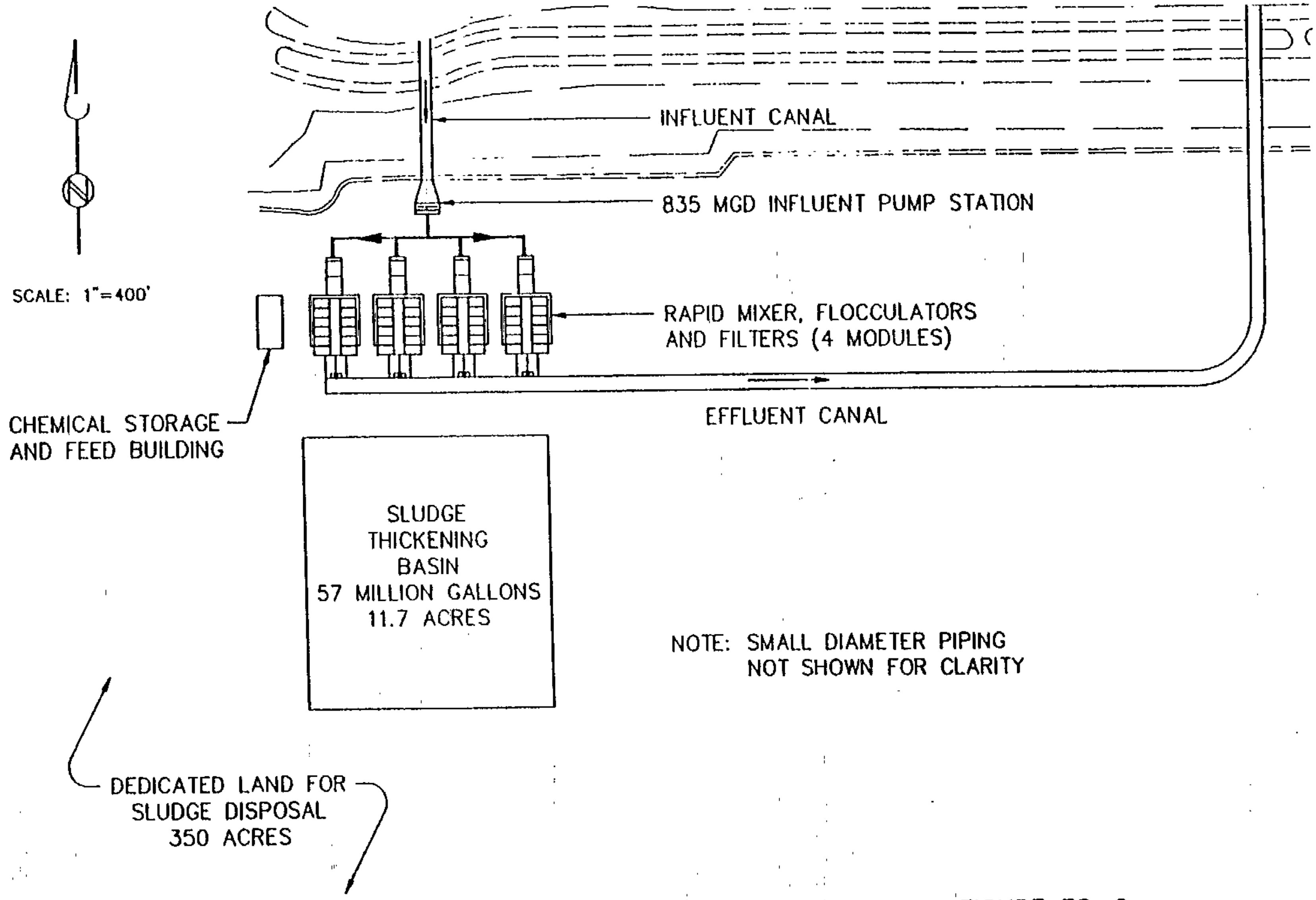

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FIGURE ES-2.
SITE LAYOUT FOR HIGH RATE
DIRECT FILTRATION AT BASIN S-5A

E:/7138/FIGES-2

Table ES-2 Present Worth Estimates of Basin-Scale Treatment Alternatives

Item	Cost, millions of December 1992 dollars			Dollars per pound of P removed
	Capital	O&M	Present Worth[a]	
Basin S-5A				
STA	118.2	3.53	152.8	96[b]
Direct filtration				
High rate				
with dedicated land disposal[c]	88.8	2.12	109.6	68[b]
with mechanical dewatering/landfill	98.6	2.98	127.8	80
Low rate[c]	109.7	2.49	134.1	84
Chemical treatment with wetlands[c]	169.9	3.61	205.3	128
Basin S-7				
STA	62.0	2.02	81.8	146
Direct filtration				
High rate[c]	34.4	1.43	48.4	86
Low rate[c]	44.0	1.64	60.1	107
Chemical treatment[c]	56.8	1.79	74.4	133

[a]Present worth = capital cost + factor (O&M cost)
Factor, based on 20 years equipment life and 8 percent discount rate = 9.8181
[b]1.60 million pounds P removed in Basin S-5A over 20 years.
[c]Costed for disposal of thickened sludge on dedicated land.
[d]0.56 million pounds P removed in Basin S-7 over 20 years.

systems would begin in September 1994, assuming an Environmental Impact Statement is not required for the alternative and permitting is completed concurrently with the design effort. The construction time frame for the Basin S-5A system is 42 months with the first quarter module of the facility (200 mgd) coming on line using the low-rate filtration system 30 months after construction initiation. This would provide partial treatment of the Basin S-5A flows in February 1997. The full plant (low-rate filters) is estimated to be brought on line in February 1998. For Basin S-7, the construction schedule is estimated to be 36 months with the first half of the plant being brought on line six months in advance of final completion, or November 1996. The full plant operation, including final startup, will be on line in May 1997.

Chemical Treatment with a Wetland and Chemical Treatment

Chemical treatment consists of chemical precipitation and coagulation in a rapid mixer; flocculation to produce a large, heavy floc; and settling in sedimentation basins. Chemical treatment is similar to direct filtration except greater amounts of coagulation chemicals are added to the water to produce floc that are larger and easier to settle; also sedimentation basins are substituted for filters. Therefore, much of the description of the direct filtration system is also applicable to chemical treatment with a wetland.

For Basin S-5A, a wetland included at the end of the chemical treatment process train provides additional P removal to achieve the objective of 0.05 mg/l in the treated effluent. The chemical treatment process train is designed to reduce the phosphorus concentration from 0.184 mg/l to 0.04 mg/l for that portion of the flow that is treated. As with the direct filtration system, only a portion of the flow is treated by the chemical system with the total blended flow (treated and bypassed flows) having a phosphorus concentration of 0.10 mg/l in the discharge to the wetland portion of the system. This alternative is called "chemical treatment with wetlands." If the follow-on wetland is not provided, the capacity of the chemical treatment facilities at Basin S-5A required to achieve a P concentration of 0.05 mg/l in the blended water would have to be greater. At Basin S-7, the influent P concentration is much less than that of Basin S-5A, and a follow-on wetland is not required.

Because more chemicals are added to the runoff waters in the chemical treatment with a wetland and chemical treatment alternatives, more sludge is produced. The technologies for sludge processing and disposal and the regulatory concerns expressed above for direct filtration apply equally to the chemical treatment with a wetland and chemical treatment alternatives.

A treatment process flowsheet for the chemical treatment with a wetland and chemical treatment alternatives is shown on Figure ES-3. The basis of design for these alternatives is presented in Table ES-3. Site layouts for these facilities are shown on Figures ES-4 and ES-5 for Basins S-5A and S-7, respectively. The estimated capital, annual O&M, present-worth costs, and cost per pound of P removed are shown in Table ES-2. In Basin S-5A, the chemical treatment system with wetland is considerably more expensive than the direct filtration system, reflecting operation of two treatment systems instead of one. In Basin S-7, the chemical treatment system is more expensive than direct filtration.

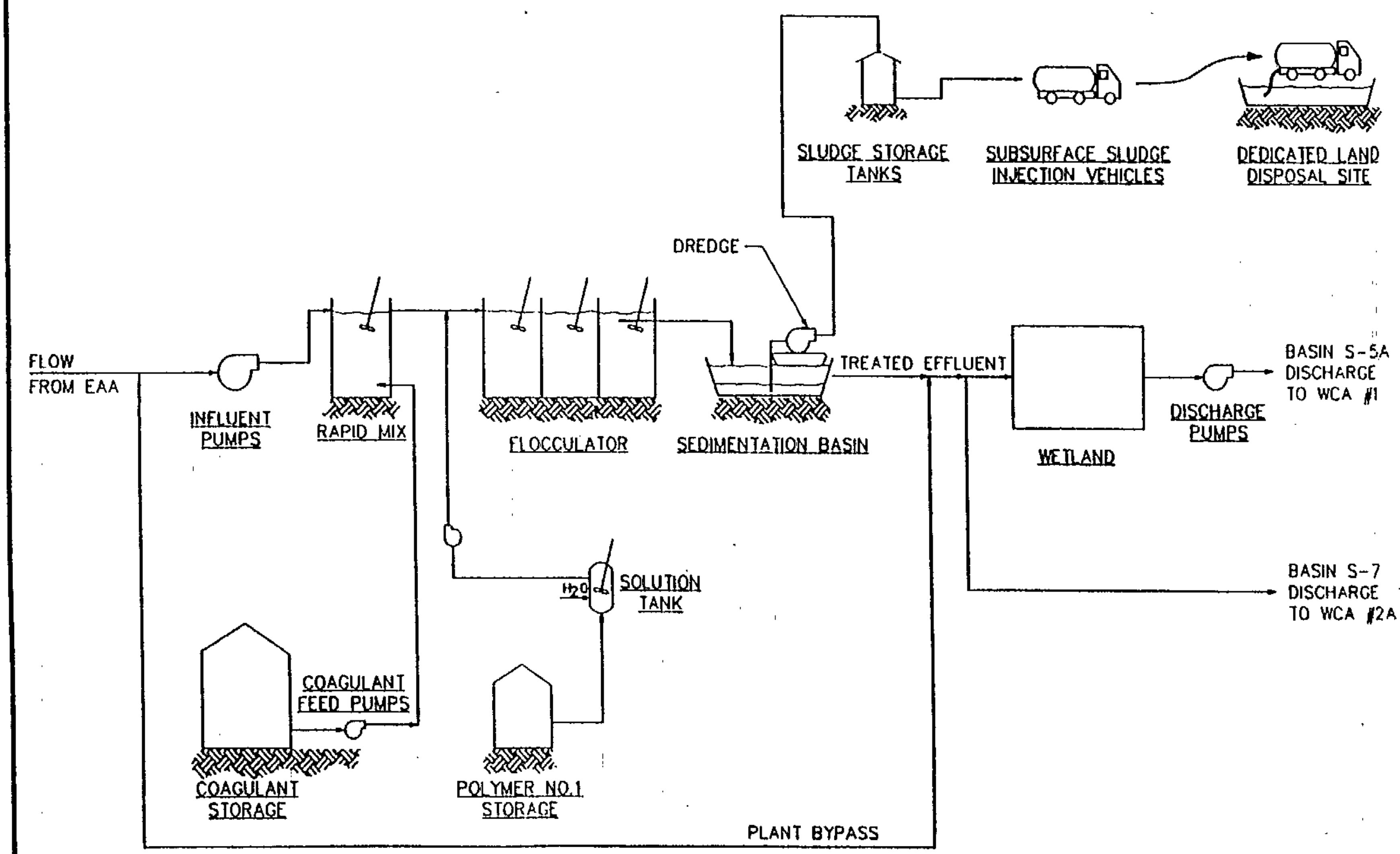

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FIGURE ES-3.
CHEMICAL TREATMENT WITH
WETLAND FLOWSHEET

E:/7138/FIGES-3

Table ES-3 Basis of Design for Chemical Treatmnent with Wetlands and Chemical Treatment

Item	Basin S-5A	Basin S-7
Basin data		
Flow, million gals		
Maximum annual	95,565	105,913
Minimum annual	41,627	28,817
Average annual	70,134	76,819
P concentration, mg/L		
Maximum annual	0.234	0.140
Minimum annual	0.121	0.056
Average	0.187	0.094
TSS concentration, mg/L		
50th percentile	19	6
90th percentile	40	14
95th percentile	58	16
Plant data		
Percent of days on line	33	71
Flow, mgd		
Maximum	570	430
Minimum	0	0
Average		
All days	114	130
When operating	347	183
Maximum year		
Average all days	152	217
When operating	462	306
Influent pumps		
Number of small pumps	1	1
Capacity each small pumps, gpm	30,000	30,000
Peak plant flow, mgd	570	430
Number of large pumps	4	4
Capacity each large pump, gpm	122,000	90,000

Table ES-3 Basis of Design for Chemical Treatment with Wetlands and Chemical Treatment (continued)

Item	Basin S-5A	Basin S-7
Flocculators		
Number, in parallel	16	12
Stages per flocculator	3	3
Volume per stage, gal	247,000	247,000
Detention time per stage at peak flow, mins	10	10
Mixer	Horiz paddle	Horiz paddle
Velocity gradient, sec^{-1}		
Minimum	20	20
Maximum	90	90
Power input per stage, HP		
Maximum	15	15
Minimum	0.7	0.7
Material of construction	Concrete	Concrete
Sedimentation basins		
Number in parallel	16	12
Depth, ft	14	14.5
Width, each, ft[a]	275	275
Length, each, ft[a]	360	360
Weir length per basin, ft	1,650	1,659
Forward displacement velocity at peak flow, ft/min	1.0	1.0
Overflow rate at peak flow, gpd/ft^2	359	359
Detention time at peak flow, hrs	6	6
Weir rate at peak flow, gpm/ft^2	15	15
Dredges		
Number	1	1
Capacity, gpm	1,500	1,500
Material of construction	Earth	Earth
Stormwater treatment area		
Area, acres	6,200	Not applicable
Width, feet		Not applicable
Length, feet		Not applicable
Discharge pumping		
Peak flow, mgd	3,102	--
Number of pumps in parallel	74	--
Capacity per pump, gpm	30,000	--

Table ES-3 Basis of Design for Chemical Treatment with Wetlands and Chemical Treatment (continued)

Item	Basin S-5A	Basin S-7
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33%	Liquid, 33%
Dose, as Fe, mg/L	$FeCl_3$	$FeCl_3$
Average		
Maximum	10	10
Pumps	15	15
Number (1 spare)		
Capacity, each, gpm	5	4
Storage tank	10	10
Volume, gals		
Liner	760,000	580,000
Storage time at peak feed rates, wks	Rubber	Rubber
	2	2
Polymer		
Form	Liquid	Liquid
Dose, mg/L		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	5	4
Capacity, each, gpm	1	1
Solution tank volume, gals	10,000	10,000
Storage tank		
Volume, gals	1,600	1,200
Storage at peak feed rates, wks	2	2
Rapid mix tanks		
Number, in parallel	4	3
Volume, each, gals	3,300	3,300
Detention time at peak plant flow, sec	2	2
Mixer	Turbine	Turbine
Velocity graident, sec^{-1}	750	750
Power input per tank, HP	14	14
Material of construction	Concrete	Concrete

Table ES-3 Basis of Design for Chemical Treatment with Wetlands and Chemical Treatment (continued)

Item	Basin S-5A	Basin S-7
Dedicated land disposal		
Sludge production, tons dry solids per year		
Maximum	9,984	9,833
Average	7,495	5,889
Maximum application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	7	7
Area per section, acres	50	49
Number of nurse tanks	7	7
Volume each nurse tank, gals	7,500	7,500
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	2	1
Spreading capacity each, gal/day	120,000	120,000
Land requirements, acres	6,717	470

[a]Excludes berm

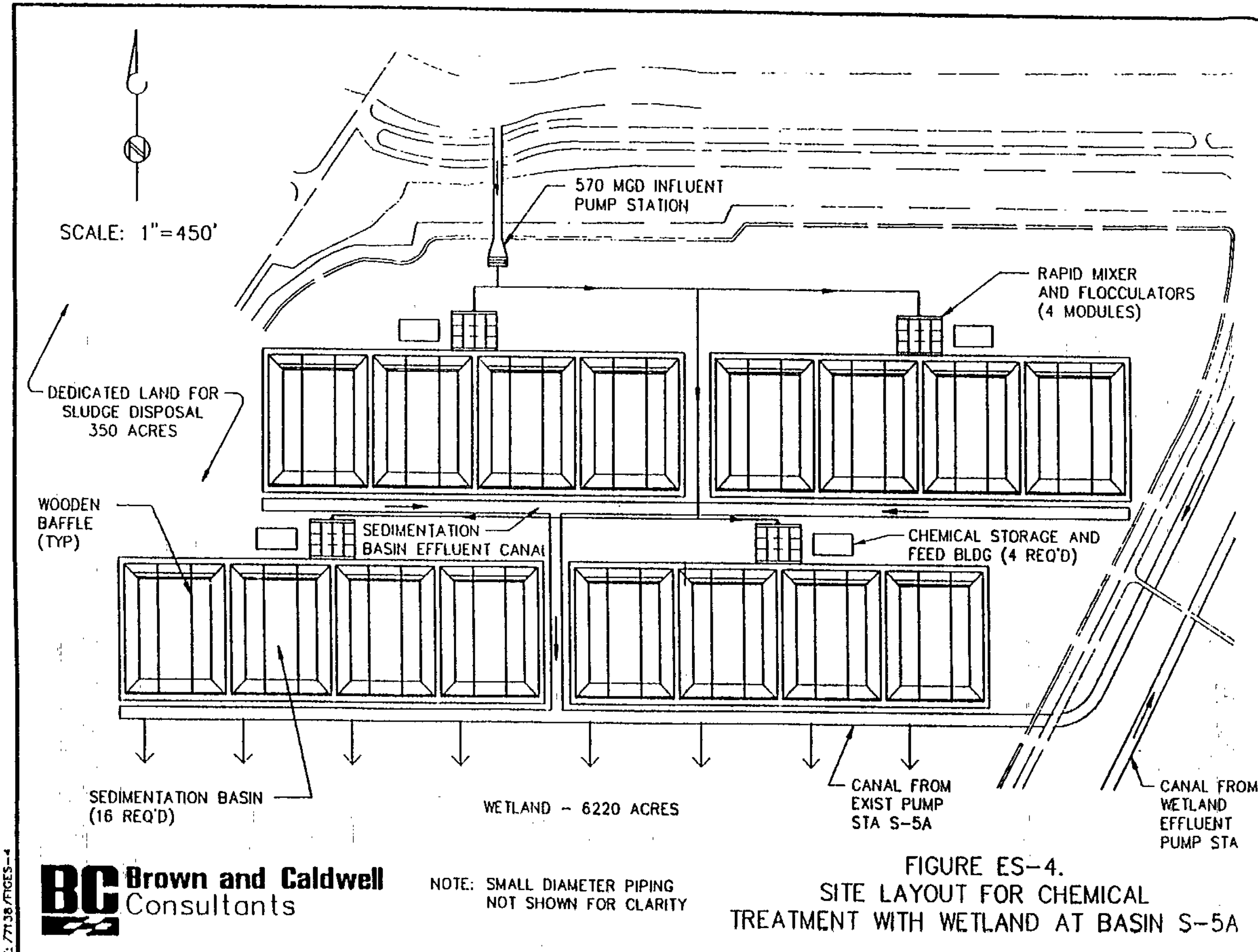
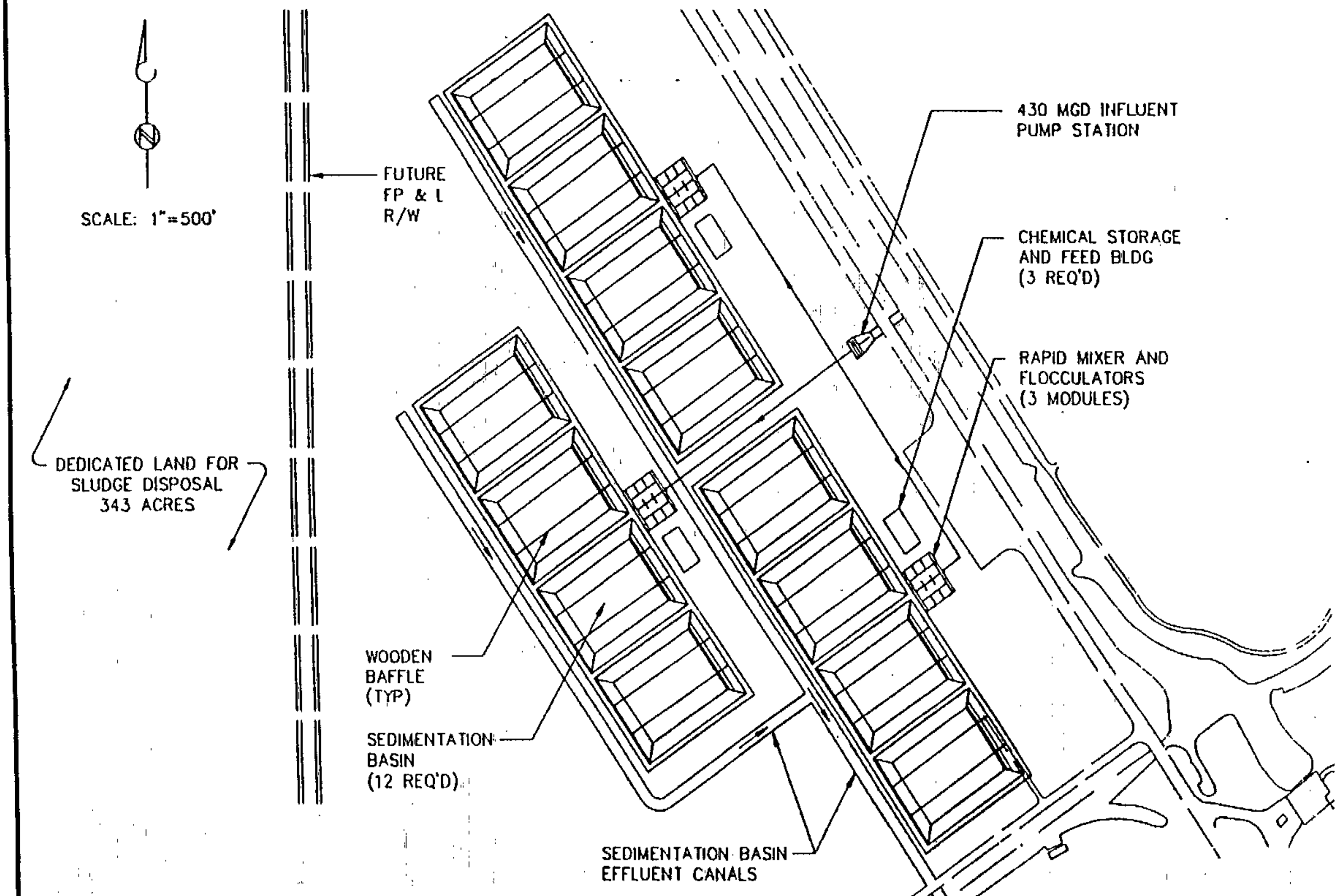


FIGURE ES-4.
SITE LAYOUT FOR CHEMICAL TREATMENT WITH WETLAND AT BASIN S-5A



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NOTE: SMALL DIAMETER PIPING NOT SHOWN FOR CLARITY

FIGURE ES-5.
SITE LAYOUT FOR CHEMICAL TREATMENT AT BASIN S-7

E:/7138/FIGES-5

The land required to implement the chemical treatment with a wetland alternative at Basin S-5A is 6,717 acres because it includes a 6,200-acre follow-on wetland. This acreage is considerably more than is required for the direct filtration alternative, but is significantly less than the acreage required for the STA. The land required to implement the chemical treatment alternative at Basin S-7 is only 470 acres because there is no follow-on wetland.

It is estimated that it will take approximately 57 months to plan, design, permit, construct and start up the chemical treatment facilities at Basin S-5A; however, additional time is required after startup to establish the equilibrium in the follow-on wetland necessary to insure sustainable P removals. The estimated implementation schedule to place a chemical treatment plant in operation at Basin S-7 is 53 months. Upon startup, the Basin S-7 chemical treatment plant will immediately produce effluent that meets the objective of 0.05 mg/l phosphorus in the blended effluent leaving the basin. As with the direct filtration alternative, only a portion of the basin flows are treated. The non-treated flows are then blended with the treated flows. The treated flow will have a phosphorus concentration of 0.04 mg/l prior to blending with the untreated flows.

Stormwater Treatment Areas (STAs)

The STAs evaluation consisted of a review of the conceptual design for the wetland treatment system based primarily on the Burns & McDonnell conceptual design report, dated March 1992. The evaluation focused on a review of the design approach to identify critical process and engineering assumptions that need to be verified as the STAs design concept is developed. The basic engineering evaluations, such as construction cost estimates, levee design, inlet/outlet structure hydraulics, flow distribution, and treatment site location, were not reviewed. The construction cost estimates were updated using the Construction Price Index to December 1992 dollars to allow for direct comparisons with the other basin scale alternatives. Operation and maintenance costs were developed for the STAs in the Basin S-5A and S-7 so that present-worth costs could be developed for the STAs.

The review of the conceptual design report raised some possible issues regarding the adequacy of the STAs to consistently reach the desired P treatment levels within the allotted time frame. The STAs are essentially constructed marshes; such wetland types have been successfully employed elsewhere for nutrient removal. The concerns associated with the design approach taken with the STAs are not so much the design particulars, but rather the insufficiency of available data upon which to base the design. The major concerns identified with the STA design can be classified as design concept issues, soil-related issues, performance issues, engineering issues, biological and other issues.

Paramount among the design concept issues is the transferability of observations within WCA 2A to the STAs, with the inherent differences in soils, P form, and historic land uses. Also within the realm of design concept issues are: P removal mechanisms; model validation; and lack of site-specific information. Soil-related issues include: soil/water column interactions; the roles of calcium and magnesium in P removal; and possible insufficiencies in soil depth in some areas. Performance issues include: reliability, ability to achieve the concentration goals within the desired time frame; along with management and control considerations. Engineering issues identified in this review include: wave action and subsequent resuspension of P; development of an accurate water balance; and flow equalization. Other issues identified during review of the STAs are: inclusion of open water in the design and property acquisition.

Phase II Evaluation Criteria

The basin scale treatment alternatives--STAs, direct filtration and chemical treatment--were evaluated using the Phase II Evaluation Criteria for both Basins S-5A and S-7. The criteria consist of two main elements, economic factors and noneconomic factors, with each factor assigned a criteria weight and ranking scale of 1 to 10. There are four economic factors: capital cost, operation and maintenance costs, revenue loss, and present-worth cost. The four economic factors have a possible point score of 350 out of the total score of 1,000 for both the economic and noneconomic factors. The noneconomic factors are subdivided into three categories--performance, consisting of seven factors having a possible total score of 380 points, environmental, consisting of eight factors having a possible total score of 200 points; and other, consisting of five factors, having a possible total score of 70 points.

The economic evaluations for Basin S-5A and Basin S-7 resulted in the direct filtration system being rated significantly higher than the chemical treatment systems and STAs. The direct filtration system for both basins is estimated to have lower capital cost, operation and maintenance cost and present-worth cost than the other two systems. The most significant difference between the alternatives is in the rating for revenue loss. The direct filtration system uses only a fraction of the land required for the STAs or chemical treatment with a wetland, and therefore is rated significantly higher for that criterion. Based on information contained in the 1992 Hazen and Sawyer report, the total annual revenue loss for the three systems for Basin S-5A and Basin S-7 are presented in Table ES-4 below.

Table ES-4 Revenue Loss Estimates for Alternative Treatment Technologies

Treatment technology	Revenue loss, million dollars	
	Basin S-5A	Basin S-7
Direction filtration	1.0	0.5
Chemical treatment with a wetland	15.7	--
Chemical treatment	--	1.2
STAs	29.0	14.7

The noneconomic evaluation resulted in the STAs being rated the highest against the environmental criteria primarily due to the increased habitat value, the improvement in downstream water quality, and the positive impact on ground and surface water conditions. The direct filtration system rated the highest against performance and other criteria. The direct filtration system rated significantly higher than the STAs and the chemical treatment systems against the key criteria of phosphorus removal capacity, implementation schedule, previous application of the technology, reliability, and flexibility. These ratings reflect the advantages that a proven, controllable technology has over a constructed wetland system that uses many removal mechanisms that are not fully understood and are marginally controllable. For the other criteria, the ratings for all three systems were similar with the direct filtration system being rated the highest overall based primarily on the land area requirement and employment criteria. For these criteria, the direct filtration system has a clear advantage over the STAs and the chemical treatment with a wetland system.

Table ES-5 presents a summary of the scoring of the technologies against the Phase II Evaluation Criteria.

Table ES-5 Summary of Treatment Technologies Scoring at the Basin Scale

Treatment technology	Basin		Maximum score per basin
	S-5A	S-7	
Direct filtration	782	828	1,000
Chemical treatment with a wetland	439	--	1,000
Chemical Treatment	--	597	1,000
STAs	523	539	1,000

FARM-SCALE ALTERNATIVE TREATMENT TECHNOLOGIES

The evaluation of farm-scale treatment alternatives is contained in Chapter 3. Direct agricultural runoff from farms contribute approximately 77 percent of the total flow and 86 percent of the P emanating from the EAA. IFAS reports average P concentrations in agricultural runoff from sugarcane and vegetable farms are 0.12 and 0.34 mg/l, respectively, using existing farming practices. Model farm flows were estimated by modeling the historic rainfall data from 1980 through 1988 adjusted for estimated evapotranspiration rates and basin-wide irrigation demands. Total suspended solids concentrations were also estimated.

The model farm treatment plants were sized using the same approach as the basin scale treatment plants for bypassing a portion of the flow. The P removal objective for the model sugarcane farm treatment systems was established at 0.05 mg/l (the same as the basin scale objective). The P removal objective for the model vegetable farm was established at 0.10 mg/l (except for the in-canal chemical treatment) because the treatment systems are not able to reduce the high untreated P concentration (0.34 mg/l) to 0.05 mg/l. The in-canal chemical treatment alternative objective was set at 0.11 mg/l because that is the lowest level obtainable even if all the flow from the vegetable farm is treated.

Chemical Treatment with Sedimentation Basins

Chemical treatment with sedimentation basins at the farms uses the same processes as basin scale chemical treatment. The basis of design for chemical treatment at the two model farms is presented in Table ES-6. The estimated capital, O&M, present-worth costs, and cost per pound of P removed for chemical treatment with sedimentation basins are summarized in Table ES-7.

Chemical Treatment Using Existing Drainage Canals

The existing drainage canals at the farms must be widened and deepened for use as chemical treatment facilities. These modifications could be done in conjunction with implementation of on-farm BMPs for controlling the groundwater table and providing more water storage. A schematic diagram of an in-canal chemical treatment system is shown on Figure ES-6. The basis of design for in-canal chemical treatment is presented in Table ES-8. Thickened sludge would be removed by dredging from the bottom of the modified canal during the dry season and disposing of it on dedicated land adjacent to the canal. The estimated capital, O&M, and present-worth costs for the in-canal chemical treatment system are shown in Table ES-7.

Farm Treatment Areas (FTAs)

FTAs are downsized versions of STAs or constructed wetlands. The same P removal mechanisms are at work in FTAs. FTAs also have the same design uncertainties as STAs. The issues and concerns expressed above for STAs apply to FTAs. The construction costs prepared in the District report on the FTAs were updated to December 1992 for comparison with the other farm scale treatment systems. Operation and maintenance costs were developed for the FTAs and present-worth costs were computed. These costs, together with the cost-per-unit reduction in phosphorus, are presented in Table ES-7.

POINT SOURCE TREATMENT ALTERNATIVES

The point sources of wastewater in the EAA include seven sugar mills and package wastewater treatment plants serving small villages and labor camps. These point sources contribute a small percentage of the total P load leaving the EAA.

Sugar mill wastewater streams are estimated to have P concentrations in the range of 20 to 30 mg/l. Possible treatment or disposal technologies for sugar mill waste streams include wetlands, chemical treatment, deep well injection, and percolation ponds. These technologies, or combinations thereof, could reduce P concentrations in discharges to EAA surface waters to between 0 (for deep well injection) and 1 mg/l. The advantages and disadvantages of the

Table ES-6 Basis of Design for Farm-Scale Chemical Treatment

Item	Model sugarcane farm	Model vegetable farm
Area, acres	6,400	1,280
Flow, million gals[a]		
Average annual	3,716	1,368
Maximum annual	5,474	1,838
Average P, mg/L[b]	0.12	0.34
Average. TSS, mg/L	13	13
Plant data		
Percent of days on line	52	52
Flow, mgd		
Maximum	27	9
Minimum	0	0
Average		
All days	8.1	3.4
When operating	15.6	6.5
Maximum year		
Average all days	11.7	4.1
When operating	22.4	7.8
Influent pumps		
Peak plant flow, mgd	27	9
Number of pumps, in parallel	3	2
Capacity each, gpm	10,000	7,500
Rapid mix tanks		
Number, in parallel	1	1
Volume, each, gal	625	210
Detention time at peak plant flow, sec	2	2
Mixer	Turbine	Turbine
Velocity gradient, sec^{-1}	750	750
Power input per tank, hp	3	1
Material of construction	Concrete	Concrete
Flocculators		
Number, in parallel	1	1
Stages per flocculator	3	3
Volume per stage, gal	187,000	62,500
Detention time per stage at peak flow, mins	10	10
Mixer	Horizontal paddle	Horizontal paddle
Velocity gradient, sec^{-1}		
Minimum	20	20
Maximum	90	90
Power input per stage, hp		
Minimum	0.5	4
Maximum	11	0.2
Material of construction	Concrete	Concrete

Table ES-6 Basis of Design for Farm-Scale Chemical Treatment (continued)

Item	Model sugarcane farm	Model vegetable farm
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33% $FeCl_3$	Liquid, 33% $FeCl_3$
Dose, as Fe, mg/L		
Average	10	10
Maximum	15	15
Pumps		
Number (1 spare)	2	2
Capacity, each, gpm	2	1
Storage tank		
Volume, gal	36,000	12,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2
Polymer		
Form	Liquid	Liquid
Dose, mg/L		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	2	2
Capacity, each, gphr	7	4
Solution tank volume, gal	275	100
Storage tank		
Volume, gal	80	30
Storage at peak feed rates, wks	2	2
Sedimentation basins		
Number in parallel	1	1
Depth, ft	14	14
Width, each, ft	208	70
Length, each, ft	360	360
Forward displacement velocity at peak flow, ft/min	1.0	1.0
Overflow rate at peak flow, gpd/ft^2	360	360
Detention time, hrs	6	6
Weir loading rate, gpm/ft	15	15
Dredges		
Number	1	1
Capacity, gpm	200	100
Material of construction	Earth	Earth

Table ES-6 Basis of Design for Farm-Scale Chemical Treatment (continued)

Item	Model sugarcane farm	Model vegetable farm
Dedicated land disposal		
Application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	1	1
Area per section, acres	23	8
Number of nurse tanks	2	2
Volume each nurse tank, gal	600	600
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	1	1
Spreading capacity each, gal/day	25,000	10,000

[a]Compiled from daily rainfall data from years 1980-1988, inclusive.
[b]IFAS, Final Report, Area 3, Volume II, January 1991.
[c]Mean of basin scale TSS calculated from District water quality data base.

Table ES-7 Present Worth of Farm-Scale Alternatives
(in millions of December 1992 dollars)

Item	Cost, millions of December 1992 dollars			Cost, dollars per pound of P removed
	Capital	O&M	Present worth[a]	
Sugarcane farm				
Chemical treatment	4.4	0.23	6.6	152[b]
In-canal chemical treatment	5.7	0.24	8.1	187[b]
FTA	5.0	0.16	6.6	152[b]
Vegetable farm				
Chemical treatment	1.9	0.14	3.3	60[c]
In-canal chemical treatment	3.2	0.14	4.6	84[c]
FTA	2.8	0.08	3.6	68[d]

[a]Present worth = capital cost + f (O&M cost) where f = 9.8181 based upon 20-year life and a discount rate of 8 percent.
[b]43,400 pounds of P removed over 20 years.
[c]54,800 pounds of P removed over 20 years.
[d]52,500 pounds of P removed over 20 years.

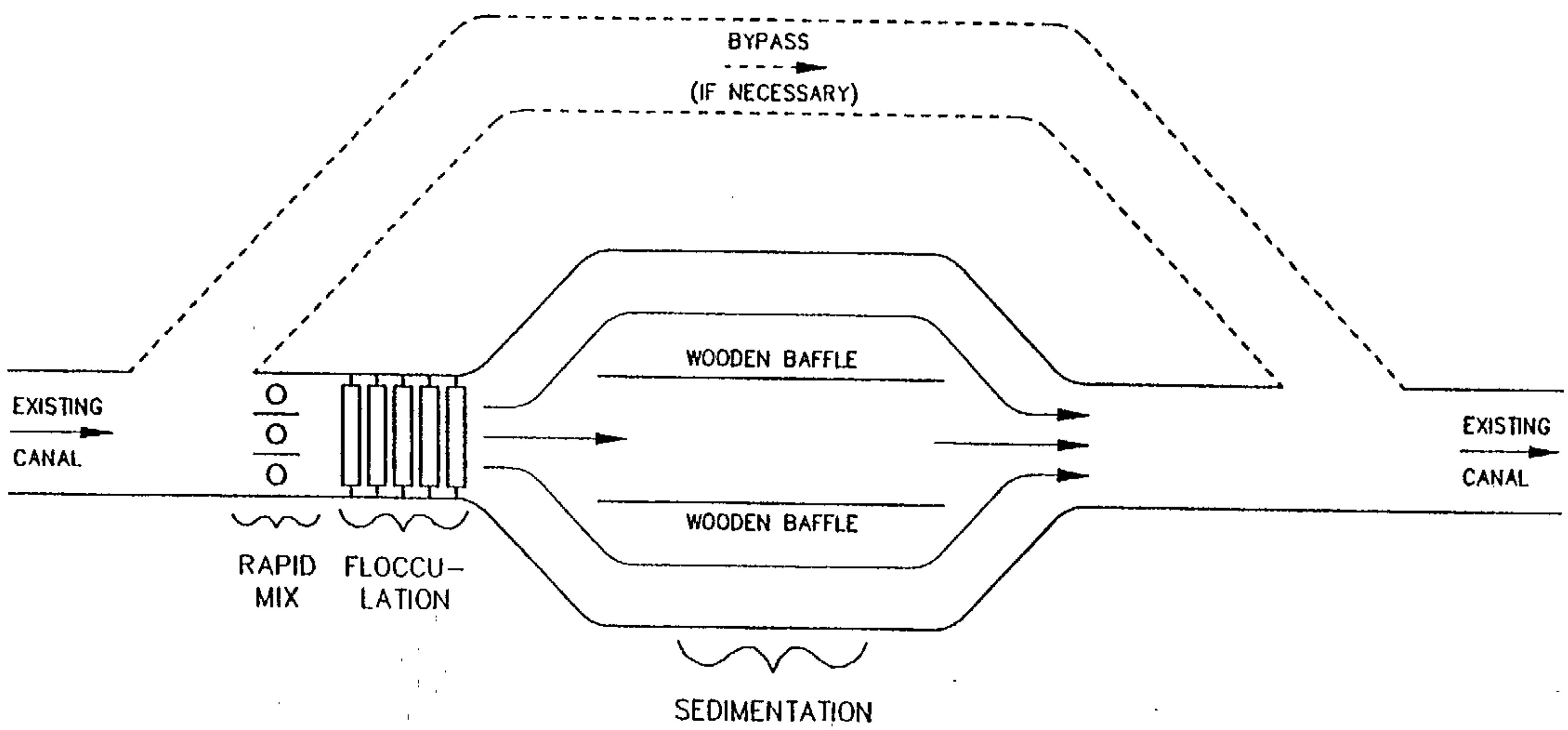

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FIGURE ES-6.
CONCEPTUAL DIAGRAM OF
FARM-SCALE IN-CANAL
CHEMICAL TREATMENT

S:/7138/FIGES-6

Table ES-8 Basis of Design for Farm-Scale In-Canal Chemical Treatment

Item	Model sugarcane farm	Model vegetable farm
Area, acres	6,400	1,280
Flow, million gals[a]		
Average annual	3,716	1,368
Maximum annual	5,474	1,838
Average P, mg/L[b]	0.12	0.34
Average, TSS, mg/L	13	13
Plant data		
Percent of days on line	52	52
Flow, mgd		
Maximum	34	16
Minimum	0	7.1
Average		
All days	9.2	3.7
When operating	17.2	7.1
Maximum year		
Average all days	13.4	5.0
When operating	25.7	9.7
Influent pumps		
Peak plant flow, mgd	34	16
Number of pumps, in parallel	3	2
Capacity each, gpm	10,000	10,000
Rapid mix tanks		
Canal width, ft	30	30
Water depth, ft	10	10
Length of rapid mix zone, ft	5	2.5
Detention time at peak flow, secs	30	30
Number of mixers	3	3
Velocity gradient, sec^{-1}	250	250
Flocculators		
Canal width, ft.	30	30
Water depth, ft	10	10
Length of flocculation zone, ft	315	148
Detention time at peak flow, min	30	30
Number of flocculators	16	8
Velocity gradient, sec^{-1}		
Minimum	20	20
Maximum	90	90

Table ES-8 Basis of Design for Farm-Scale In-Canal Chemical Treatment (continued)

Item	Model sugarcane farm	Model vegetable farm
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33% $FeCl_3$	Liquid, 33% $FeCl_3$
Dose, as Fe, mg/L		
Average	10	10
Maximum	15	15
Pumps		
Number (1 spare)	2	2
Capacity, each, gpm	3	1.5
Storage tank		
Volume, gal	61,000	31,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2
Polymer		
Form	Liquid	Liquid
Dose, mg/L		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	2	2
Capacity, each, gphr	10	7
Solution tank volume, gal	350	200
Storage tank		
Volume, gal	100	50
Storage at peak feed rates, wks	2	2
Sedimentation basins		
Number	1	1
Width, ft	263	124
Length, ft	360	360
Depth, ft	15	14
Maximum forward flow at peak flow, ft/min	1	1
Detention time at peak flow, hours	6	6
Overflow rate at peak flow, gpd/ft^2	360	360
Dredges		
Number	1	1
Capacity, gpm	100	40

Table ES-8 Basis of Design for Farm-Scale In-Canal Chemical Treatment (continued)

Item	Model sugarcane farm	Model vegetable farm
Dedicated land disposal		
Application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	1	1
Area per section, acres	35	14
Number of nurse tanks	2	2
Volume each nurse tank, gal	600	600
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	1	1
Spreading capacity each, gal/day	40,000	15,000

[a]IFAS, Final Report, Area 3, Volume II, January 1991.
[b]Compiled from daily rainfall data from years 1980-1988, inclusive.
[c]Mean of basin scale TSS calculated from District water quality data base.

possible technologies for the sugar mills are presented in Chapter 4.

Package plants are small, preconstructed, activated sludge treatment systems designed to serve small populations. They are not usually designed for P removal. Possible treatment technologies for removing phosphorus from package plant effluents include follow-on wetlands, chemical addition to the existing treatment units, new sedimentation tanks, and direct filtration. Chemical addition to the existing treatment units using alum or iron salts would be the most cost-effective technology in most cases.

UNIT COST FOR PHOSPHORUS REMOVAL

For the farm and basin scale alternatives, the per-unit (pound) cost was computed using the present-worth cost and the total life cycle mass of phosphorus removed by the treatment systems. The comparison of the alternatives on this basis will be useful in evaluating the cost-effectiveness of the alternative treatment technologies at the two different scales of application. From this information, conclusions can be drawn as to whether it is most cost-effective to reduce the phosphorus load at the farm or basin scale. Equally important, the unit-cost removal will allow a comparison of the treatment technologies to BMPs that are being evaluated to achieve on-farm reductions of 25, 35, and 45 percent.

At the basin scale, the unit costs for the alternative treatment systems range from \$68/lb to \$128/lb in Basin S-5A, and from \$86/lb to \$146/lb in Basin S-7. With the lower phosphorus concentration and load in Basin S-7, the unit costs are significantly higher for all the technologies. However, the STAs have the most significant increase--\$96/lb to \$146/lb compared with the increases of \$68/lb to \$86/lb and \$80/lb to \$107/lb for the direct filtration high- and low-rate systems, respectively. A direct comparison of the unit cost for chemical treatment with a wetland and for chemical treatment in the Basin S-5A and S-7, respectively, is not meaningful since the systems do not contain the same treatment processes.

For the farm scale treatment technologies, the unit removal cost range is \$152/lb for the chemical treatment and FTA systems, and \$187/lb for the in-canal chemical treatment system. With the higher phosphorus load from the vegetable farm, the unit costs are significantly reduced--\$60/lb for the chemical treatment system, \$68/lb for the FTAs, and \$84/lb for the in-canal treatment system. The vegetable farm unit cost, however, cannot be directly compared with the sugarcane farm or basin scale systems because the discharge from the vegetable farm systems is 0.10 mg/l compared to the 0.05 mg/l level for the other systems. The vegetable farm discharge would have to receive additional treatment before it would meet the 0.05 mg/l phosphorus level for discharge from the EAA.

The companion document to this report is the Evaluation of the On-Farm Best Management Practices currently being prepared by Brown and Caldwell. The unit removal cost for the combinations of BMPs to achieve reductions of 25, 35, and 45 percent reductions for sod, vegetables, and sugarcane are presented in Table ES-9. The unit cost for the farm and basin scale treatment systems are summarized in Table ES-10.

Table ES-9 Summary of Costs for BMP Combinations on a Load Basis

Phosphorus load reduction, percent	Cost of BMP implementation, dollars per pound phosphorus removed			
	Sugarcane[a]	Vegetables[b]	Sod[c]	EAA
25	3.52	(31.51)	56.38	0.58
35	5.27	(10.94)	141.85	13.08
45	46.86	58.96	218.62	103.13

[a] Costs based on assumed annual phosphorus loading of 0.58 pounds phosphorus/acre/year.
[b] Costs based on assumed annual phosphorus loading of 2.11 pounds phosphorus/acre/year.
[c] Costs based on assumed annual phosphorus loading of 0.74 pounds phosphorus/acre/year.

The development of a recommended plan for meeting the requirements of the SWIM Plan will involve a combination of the BMPs and a basin scale treatment system. The unit cost for removal of phosphorus at the farm and basin scales will be a necessary tool used in the development of a plan that provides a reliable, implementable treatment system at a reasonable cost. The Plan Formulation phase is underway by the District, and this analysis will assist in developing a mix of treatment technologies and BMPs to develop a reliable plan for the S-5A, S-6, S-7, and S-8 basins.

CONCLUSIONS AND RECOMMENDATIONS

Background

With the evaluation of the alternative technologies, the District initially started with 16 treatment technologies, four scales of application for these treatment technologies and three desired levels of phosphorus load reduction. The purpose of the evaluation was 1) to determine which, if any, of the treatment technologies could be competitive with the STAs, at the basin scale; 2) to determine whether the effectiveness of the technologies varied significantly for the four scales of application; 3) to determine whether the effectiveness of the technologies varied with the amount of phosphorus that was required to be removed; and 4) to develop a basis on which technologies and BMPs can be evaluated in the Plan Formulation Phase of the Everglades Protection Project. The conclusions from the alternatives analysis with respect to these four goals are:

1. Except for the direct filtration system and chemical treatment systems, the STAs are superior to the other technologies at the basin scale.

Table ES-10 Summary of Unit Costs for Farm and Basin Scale Treatment Systems

Scale and treatment system	Present worth cost,[a] dollars/pound P removed
Sugarcane farm	
Chemical treatment	$152
In-canal chemical treatment	187
FTA	152
Vegetable farm	
Chemical treatment	60
In-canal chemical treatment	84
FTA	68
Basin S-5A	
STA	96
Direct filtration	
High rate	
with dedicated land disposal	68
with mechanical dewatering/landfill	80
Low rate	84
Chemical treatment with wetlands	128
Basin S-7	
STA	146
Direct filtration	
High rate	86
Low rate	107
Chemical treatment	133

[a]Costs in December 1992 dollars.

2. The wetlands and chemical treatment systems were found to be applicable at all scales of application. The direct filtration system is more appropriate for basin or sub-basin scales of application.

3. There was little variability in the overall effectiveness of the treatment technologies evaluated in this report for the selected range of phosphorus load reductions. The chemical treatment and direct filtration systems are capable of treating the widest range of phosphorus loads. With regard to the STAs, the evaluation raised concern over the ability of the STAs to achieve the higher load reduction goals (i.e., over 50 percent reduction).

4. To assist in the Plan Formulation Phase for each basin, the unit cost for phosphorus removal was determined for the alternative technologies at the farm and basin scales and for the on-farm BMPs.

Basin Scale

For the basin scale alternative technologies, the Phase II Evaluation Criteria were utilized to evaluate the effectiveness and applicability of the STAs, chemical treatment, chemical treatment with a wetland, and direct filtration technologies. Using the Phase II criteria, the direct filtration system is the highest rated technology for both Basin S-5A and Basin S-7 by over 250 points for Basin S-5A and 230 points for Basin S-7. The STA in Basin S-5A is the second rated technology with the chemical treatment being rated higher for Basin S-7.

The Phase II Evaluation Criteria are designed to be useful tools in comparing the three technologies over a comprehensive set of weighted criteria. The criteria were not designed to be applied blindly without sound scientific and engineering judgment. In determining which technologies should be recommended for further consideration, the overall ability of the technology to meet the treatment goal is the critical parameter. For the chemical treatment technology with or without a wetland system, the ability of large, uncontrolled sedimentation basins to consistently and reliably reduce phosphorus to the 0.05 mg/l level is questionable. Effects of wind, sludge resuspension, and short-circuiting are all critical design parameters that would need considerable study to accurately quantify. The decision not to recommend further evaluation of this technology is also significantly impacted by the present worth cost of the chemical treatment system as compared with direct filtration. With the present worth cost being over 20 percent higher than the low-rate direct filtration system, continued development of a second treatment system utilizing chemical addition appears redundant.

The development of the STA design has had continued refinement since the conceptual design report by Burns & McDonnell was issued in March 1992. Based on this March report, there are numerous areas of concern previously outlined in this Executive Summary. It is recommended that the STAs continue to be developed as part of the Plan Formulation Phase of the Everglades Protection Project. This continued development needs to address the issues raised in this report, both as to the technical merits of the issues, and the cost impacts of addressing these areas of concern.

In addition to continuing the development of the STAs for the four basins, it is recommended that the direct filtration system be a part of the final Plan Formulation Phase. As a part of this further development, a direct filtration system should be developed conceptually for all four EAA basins. It is also recommended that bench scale tests be initiated to verify the assumptions on chemical dosages used in this evaluation and to determine impacts to the water chemistry of the chemical addition. Provided the bench scale test is successful, a pilot test phase is recommended to verify the flash mix and flocculation mixing intensity and contact times used in this evaluation and to compare various filter loading rates to determine whether the high- or low-rate system should be used.

The recommendation of continued evaluation of the direct filtration alternative is based on the following key factors:

1. **Cost.** The estimated construction and operation and maintenance costs are materially lower than the STAs for the Basin S-5A and S-7.

2. **Less Land Required.** Direct filtration requires 424 acres of land, including sludge disposal, at Basin S-5A, while the STA requires 12,200 acres. At Basin S-7, direct filtration requires 186 acres, while the STA requires 6,220 acres. This means not only lower capital costs for the purchase of land, but also less revenue loss to the community as a result of not removing nearly as much agricultural land from production.

3. **Flexibility.** One of the key elements of the Plan Formulation Phase is the ability of treatment systems to respond to the changes in the flow and phosphorus load that must be treated. With the ongoing development of the on-farm BMPs, the ability to expand or downsize the basin scale treatment system to adjust to flow and phosphorus reductions required by the BMPs is desirable. As with many elements of the Everglades Protection Project, predictions about the long-term performance of the BMPs will be developed over several years as research and data-gathering continues. Using Basin S-5A and Basin S-7 as extreme conditions that could occur in the EAA runoff, the direct filtration system showed that it has the most flexibility to treat a wide range of flows and loads.

4. **Reliability.** The ability to accurately predict the performance of the basin scale treatment system is a critical factor in the implementation of the Everglades Protection Project. The use of direct filtration has been successfully demonstrated in the Wahnbach Reservoir Direct Filtration Plant over the past 15 years. Through the utilization of bench and pilot scale testing which can be accomplished during the remainder of 1993, the design criteria can be established to fully develop the operating parameters for the facility.

5. **Implementability.** With the direct filtration system, the implementation schedule includes a construction time frame ranging from 30 to 42 months, with startup phased such that sections of the plant can be on-line after the initial 24-month

construction period. With the relatively small amount of land to be purchased, the implementation schedule is less likely to be significantly impacted by legal issues raised during the land acquisition phase. In comparison with the STAs, the direct filtration system requires only a short startup phase. For the STAs, one of the unresolved issues is the time required for the constructed wetland to develop and be fully functional once the initial construction is complete.

5) **Ability to Achieve Lower Phosphorus Levels.** The conceptual design of the direct filtration system has been based on achieving a phosphorus reduction to 0.010 mg/l. The highly treated water is blended with untreated bypass water to achieve the target long-term phosphorus concentrations of 0.050 mg/l. However, based on the period of record data used in the development of the basin scale alternatives, for 74 percent of the discharge events in Basin S-5A and 56 percent in Basin S-7, there will be no bypass and the phosphorus levels discharged from these basins would be 0.010 mg/l. If future reductions in the long-term phosphorus concentrations are required, then the bypass volumes could be reduced by expanding the direct filtration system, adding flow equalization prior to the treatment system to reduce bypass events or treating the bypass flow in a wetland system specifically sized for the bypass flows.

Farm Scale

The practicality of relying on farm scale treatment systems to meet the requirements of the SWIM Plan would need to be based on a significant reduction in the cost of the farm treatment system in relation to the basin scale system. In the EAA, there are approximately 170 permitted dischargers which would each have to operate a treatment system. These treatment systems would need to be monitored frequently for compliance with permit goals. The unit cost for phosphorus removal provides a mechanism to determine whether large-scale application of on-farm treatment systems merits further consideration. For treatment systems on the model sugarcane farm, unit costs are higher than at the basin scale. For the model vegetable farm, unit costs are less than at the basin scale. However, the vegetable discharge would still require additional treatment to achieve an effluent phosphorus concentration of 0.050 mg/l. In comparing the unit cost of on-farm BMPs to the farm scale treatment systems, the use of farm scale treatment systems may be warranted for vegetable and sod farms to achieve phosphorus load reductions of greater than 35 percent. The recommended treatment systems to be considered for sod and vegetable farm applications would be chemical treatment and the FTAs.

Point Sources

The point sources and wastewater treatment plants and sugar mill waste treatment systems are regulated by the FDER and USEPA through operating and discharge permits. The contributions of the municipal wastewater discharge has been eliminated through implementation of deep-well injection as the disposal method for the municipal discharges in the EAA. The contribution of the small package wastewater treatment plants are minor but do discharge phosphorus in concentrations significantly above the 0.050 mg/l concentration required for discharge from the EAA. The addition of a ferric salts or alum to the existing treatment process units is a viable means of improving the phosphorus levels in the package plant discharges.

Evaluating the impact of past waste treatment and disposal practices over the historical period of record is currently in progress. The results of this evaluation will be used to further characterize the waste systems and provide the necessary data to fully evaluate the appropriateness of additional treatment to the current treatment practices. The sugar mill evaluation will be finalized prior to the final draft of this report being issued.

CHAPTER 1

INTRODUCTION

This report documents work performed during the Phase II evaluation of alternative treatment technologies for reducing phosphorus discharges from the Everglades Agricultural Area (EAA). The report is in fulfillment of the work authorized under Amendment No. 4 to Contract C-3051 between the South Florida Water Management District (District) and Brown and Caldwell.

BACKGROUND

In March 1992, the District's Governing Board adopted the Everglades Surface Water Improvement and Management (SWIM) Plan consistent with a Settlement Agreement between the United States, the Florida Department of Environmental Regulation, and the District. The primary objective of the SWIM Plan is to reduce phosphorus discharges from the EAA while maintaining suitable hydroperiod in water conservation areas and the Everglades National Park. The strategy contained in the current SWIM Plan includes the following primary elements:

1. The construction and operation of four Stormwater Treatment Area (STAs) which will be large-scale constructed wetland treatment systems which will process storm runoff for the removal of nutrients.

2. The initiation of a regulatory program having as its goal the reduction of present total phosphorus loads discharged from the EAA by 25 percent. That regulatory program is to include the development and implementation of best management practices (BMPs) by property owners in the EAA.

3. The initiation and maintenance of a comprehensive, long-term multiagency research and monitoring program intended to:

    a. Numerically define applicable water quality standards.

    b. Assess current and continuing responses of the Everglades Protection Area to nutrient input levels.

In approving the SWIM Plan, the District's Governing Board committed to minimizing economic impacts on the area by continuing to consider alternatives that could satisfy the mandated performance requirements of the Settlement Agreement and to amend the SWIM Plan if necessary. In April 1992, the District hired Brown and Caldwell to assist in the evaluation of alternative treatment technologies for possible inclusion in the SWIM Plan in conjunction with the wetland systems currently proposed.

The first step in the alternatives evaluation process (Amendment No. 1) was the development of the methodology and criteria to be used in performing the evaluation. The results of the Amendment No. 1 work were submitted to the District in a report entitled "Evaluation of Alternative Treatment Technologies--Evaluation Methods and Procedures." Evaluation of alternative treatment technologies has been accomplished using a two-phase approach. The purpose of the Phase I evaluation of alternative treatment technologies (Amendment No. 2) was to identify those technologies that have the greatest potential to become meaningful components of the District's SWIM Plan, based on information currently available, and to eliminate other technologies from further consideration. The results of the Amendment No. 2 work were submitted to the District in a final draft report dated January 19, 1993, and entitled "Phase I Evaluation of Alternative Treatment Technologies." Reducing the available technologies to those that have the most promise for application in the EAA at the present time facilitates the more detailed Phase II evaluation, which is the subject of this report.

The Phase I evaluation contained recommendations of treatment technologies to be applied to site specific flows and phosphorus loads at the basin scale, subbasin scale, farm scale and point source scale in the EAA. After discussion of the Phase I results with District staff, however, it was decided that it would be more appropriate to apply the recommended technologies to seven model waste streams in the EAA. These included the following:

1. Basin S-5A, representing a basin scale waste stream with historically high phosphorus concentrations.

2. Basin S-7, representing a basin scale waste stream with historically low phosphorus concentrations.

3. A 6,400-acre model sugarcane farm.

4. A 1,280-acre model vegetable farm.

5. Package wastewater treatment plants.

6. Municipal wastewater treatment plants.

7. A typical sugar mill.

The evaluation of treatment technologies at the subbasin scale was deleted from the scope of the Phase II evaluation because the Phase I evaluation showed no advantage to treatment at this scale over the basin or farm scale. Furthermore, emphasis was to be given to the evaluation of basin and farm scale alternatives. Evaluation of alternatives for point source discharges was to be limited to a qualitative assessment, pending the results of other ongoing studies.

The following paragraphs define the alternatives that were developed and evaluated in the Phase II evaluation for each of the model waste streams.

Basin S-5A

The top-rated technologies at the basin scale proposed for detailed evaluation in Phase II included wetlands (i.e., Stormwater Treatment Areas, or STAs), chemical treatment with wetlands (involving chemical pretreatment to allow the natural marsh to reduce phosphorus concentrations to lower levels more reliably than might otherwise be achieved in unmanaged wetlands), and direct filtration. Conditional technologies that were considered include chemical treatment (without a follow-on wetland) and one-time dredging to remove sediments from District canals. One-time canal dredging is not an ongoing treatment process and was not considered in this evaluation. Based on the direction cited above and discussions with District staff, we have evaluated the following treatment technologies for Basin S-5A in Phase II:

1. Wetlands. A review of the assumptions used in the conceptual design of the STAs was performed.

2. Direct filtration.

3. Chemical treatment with wetlands consisting of chemical addition followed by sedimentation basins (earthen basins as opposed to concrete basins) with final treatment in a downsized wetland. Sedimentation basins were substituted for overland flow in the chemical treatment with a wetland alternative because of potential O&M, crop harvesting, and crop marketing problems associated with overland flow.

The evaluation of the treatment technologies for Basin S-5A was based on achieving an effluent phosphorus concentration of 0.05 mg/l.

Basin S-7

The evaluation included the following treatment technologies for Basin S-7 in Phase II:

1. Wetlands. A review of the assumptions used in the conceptual design of the STAs was performed.

2. Direct filtration.

3. Chemical treatment consisting only of chemical addition followed by sedimentation in earthen basins. A smaller follow-on wetland is unnecessary because of the lower phosphorus concentrations in Basin S-7.

The evaluation of the treatment technologies for Basin S-7 was based on achieving an effluent phosphorus concentration of 0.05 mg/l.

Model Sugarcane Farm

In the Phase I evaluation, the top-rated technologies for individual farms proposed for detailed evaluation in Phase II included wetlands (Farm Treatment Areas, or FTAs), chemical treatment with wetlands, and chemical treatment. Overland flow was identified as a conditional technology for consideration in Phase II but was not considered for the farm-scale evaluation for the reasons cited above under Basin S-5A.

The evaluation included the following treatment technologies for the model sugarcane farm in Phase II:

1. Wetlands. A review of the FTA design assumptions was performed to evaluate the viability and reliability of constructing an FTA at the model sugarcane farm.

2. Chemical addition followed by sedimentation in earthen basins (in lieu of chemical treatment with wetlands with overland flow).

3. Chemical addition followed by sedimentation in an existing drainage canal that has been modified to provide a settling and sludge storage zone.

The evaluation of the treatment technologies for the model sugarcane farm was based on achieving an effluent phosphorus concentration of 0.05 mg/l.

Model Vegetable Farm

The evaluation included the following treatment technologies for the model vegetable farm in Phase II:

1. Wetlands. A review of the FTA design assumptions was performed to evaluate the viability and reliability of constructing an FTA at the model vegetable farm.

2. Chemical addition followed by sedimentation in earthen basins. A follow-on wetland was not necessary to achieve the target phosphorus reduction level.

3. Chemical addition followed by sedimentation in an existing drainage canal that has been modified to provide a settling and sludge storage zone.

The evaluation of the treatment technologies for the model vegetable farm was based on achieving an effluent phosphorus concentration of 0.10 mg/l because of the high phosphorus concentration in untreated vegetable farm runoff.

Package Wastewater Treatment Plant

In the Phase I evaluation, the top-rated technologies for point sources such as package wastewater treatment plants and sugar mills included chemical treatment with wetlands, deep well injection, and percolation ponds. Conditional technologies to be considered in Phase II included chemical treatment and overland flow. The Phase II evaluation did not consider overland flow for point sources for the reasons cited above under Basin S-5A. All appropriate treatment technologies for a typical package wastewater treatment plant in Phase II were considered, but the evaluation concentrated on the following technologies with the objective of establishing appropriate effluent limitations that would be imposed in an NPDES permit:

1. Wetlands.

2. Chemical treatment.

3. Direct filtration.

Sugar Mills

To evaluate potential treatment technologies for sugar mills, phosphorus loads were estimated for all seven plants based on the data developed by CH_2M Hill for the Clewiston mill. The evaluation includes the following treatment technologies for a typical sugar mill with the objective of establishing appropriate effluent limitations that would be imposed in an NPDES permit that included a phosphorus limit:

1. Wetlands.

2. Chemical addition followed by sedimentation basins.

3. Deep well injection.

4. Percolation ponds.

REPORT ORGANIZATION

This report presents our Amendment No. 4 work on detailed evaluation of selected alternative treatment technologies on specific waste streams in the EAA. This report is organized into five chapters. Following this introduction, the treatment alternatives for Basins S-5A and S-7 are developed in Chapter 2. The treatment alternatives for model sugarcane and vegetable farms are developed in Chapter 3. Treatment alternatives for point sources such as sugar mills and package treatment plants and the existing process treatment and disposal facilities for the municipal wastewater treatment plants are described in Chapter 4. The conclusions of the Phase II evaluation of alternative treatment technologies and recommendations for future action are presented in Chapter 5.

ACKNOWLEDGEMENTS

Brown and Caldwell wishes to acknowledge the assistance provided by the District's Construction Management Department, Engineering Division during performance of the BMP evaluation. Specifically, the time and effort given by Mr. Zan Kugler, Engineering Division Director, and Ms. Jennifer Barone and Ms. Karin Landers of the Engineering Division staff, contributed significantly to the successful completion of the project. Appreciation also goes to Dr. George Tchobanoglous of the University of California at Davis and Mr. Woody Reed who provided valuable technical assistance and review during preparation of the Phase I and Phase II evaluation of alternative treatment technologies.

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CHAPTER 2

BASIN-SCALE TREATMENT ALTERNATIVES

Chapter 2 consists of a discussion of the methods by which loadings were calculated for basin-scale treatment alternatives and describes basin-scale alternative treatment technologies, capital costs, operation and maintenance costs, and projected schedules for implementation. Table 2-1 shows the treatment technologies evaluated at the basin scale. Direct filtration consists of phosphorus precipitation and floc formation, followed directly by filtration with no intervening sedimentation. Chemical treatment consists of chemical precipitation and floc formation, followed by sedimentation in low-cost earthen basins. Stormwater treatment areas (STAs) are large wetlands where phosphorus is removed by uptake in growing plants and microorganisms by reactions with the soil and by sedimentation. Chemical treatment with wetlands consists of chemical treatment systems followed by wetlands smaller than the STAs.

Table 2-1 Basin-Scale Phosphorus Removal Alternatives

Basin S-5A	Basin S-7
Direct filtration	Direct filtration
Chemical treatment with a wetland	Chemical treatment
Stormwater treatment area (STA)	STA

DEVELOPMENT OF DESIGN DATA

Data received from the South Florida Water Management District (District) for pumped flow at the pumping stations at Basins S-5A and S-7 were compiled along with load data generated through a regression analysis conducted by the District. The estimated distribution of total suspended solids (TSS) for Basins S-5A and S-7 was determined using information from the District's water quality data base. The following sections describe how raw data were subsequently adjusted to account for anticipated implementation of on-farm Best Management Practices (BMPs). Results of this analysis yielded future estimates on flow, phosphorus, and TSS loads and long-term, basin-scale phosphorus concentration emanating from the Everglades Agricultural Area (EAA).

Computation of Basin Flows and Phosphorus Loads

Raw basin flow and phosphorus load data were broken down by the District into outputs from each basin (basin output) and releases from Lake Okeechobee (basin flow-through). EAA runoff was calculated daily as the flow pumped out of a basin minus flow through the basin. Daily flows were summed to annual flows over the 9.75-year period of record from January 1979 through September 1988. Similarly, EAA phosphorus load data were generated over the 9.75-year period by subtracting loads released from Lake Okeechobee from loads associated with pumping events at each basin discharge point.

It has been stated that implementation of BMPs at the farms will result in a 20 percent reduction in flows and a 25 percent reduction in phosphorus loads from EAA runoff. These reduction factors were applied to EAA runoff flows and phosphorus loads. The flows and phosphorus loads, adjusted for BMPs, were then recombined with Lake Okeechobee flows and loads. The adjusted totals represent the basin flows and phosphorus loads requiring treatment in the future for Basin S-5A and Basin S-7. The calculations are described below in greater detail.

Flow Adjustments. Flow data includes only non-zero, positive pumping flow events from the EAA into the WCAs. These flow data from each basin were modified using the following method:

Q_T = total flow into the WCAs from a particular basin
Q_{EAA} = flow from Everglades Agricultural Area of a particular basin
Q_{FT} = flow from Lake Okeechobee that "flows through" the basin
Q'_{EAA} = flow from Everglades Agricultural Area of a particular basin adjusted for BMPs
Q'_T = total flow into the WCAs from a particular basin adjusted for BMPs

$Q_T = Q_{EAA} + Q_{FT}$ therefore,

$Q_{EAA} = Q_T - Q_{FT}$.

Assume that the Q_{EAA} is reduced by 20 percent due to BMPs; therefore,

$Q'_{EAA} = 0.80\ (Q_{EAA})$ and,

$Q'_T = Q'_{EAA} + Q_{FT}$.

Flows calculated using the above method were used in determining the flow into treatment units in Basins S-5A and S-7.

On some days, flow and/or phosphorus load through the basin (i.e., lake releases) was greater than flow and/or load out of the basin (pumped). This situation created negative flows and/or phosphorus loads when employing the above method for adjusting the BMPs. When negative flows were calculated, the following rule was used:

FT = flow through a basin (i.e., lake releases)
FO = flow out of a basin
ER = EAA runoff flow
RF = Reduction factor due to BMPs (0.80 for flow)
AFO = Adjusted flow out of a basin

(1) If FO - FT <= 0, (i.e., a negative or zero ER),

then AFO = FO,

(2) If FO - FT >0, (i.e., a positive ER),

then AFO = ER * RF + FT.

Load Adjustments. The load data were modified as follows:

L_T = total phosphorus load into the WCAs from a particular basin
L_{EAA} = phosphorus load to the EAA from a particular basin
L_{FT} = phosphorus load from Lake Okeechobee that "flows through" the basin
L'_{EAA} = phosphorus load to the EAA from a particular basin adjusted for BMPs
L'_T = total phosphorus load into the WCAs from a particular basin adjusted for BMPs

$L_T = L_{EAA} + L_{FT}$ therefore

$L_{EAA} = L_T - L_{FT}$.

Assume that the L_{EAA} is reduced by 25 percent due to BMPs; therefore,

$L'_{EAA} = 0.75\ (L_{EAA})$ and,

$L'_T = L'_{EAA} + L_{FT}$.

Phosphorus loads using the above method were used in determining the phosphorus load into treatment units in Basins S-5A and S-7.

The above calculations do not include reduction of flows and loads that would occur when farmland is taken out of service and converted to STAs. Therefore, the calculations result in appropriate flows and loads influent to the alternative treatment technologies.

However, approaches using chemical treatment with wetlands will employ use of currently productive farmland for the chemical treatment with wetlands. Influent flows and loads from each basin should be modified if further, detailed analysis of the chemical treatment with a wetland alternative is warranted. Likewise, if flow equalization is to be used with the alternative technology solutions, flows and loads would have to be reduced from flows and loads as calculated above.

Tables 2-2 and 2-3 show the flows and loads both before adjustment (i.e., unadjusted data as furnished by the District) and after adjusting the EAA runoff components for farm BMPs. As shown in Tables 2-2 and 2-3, the long-term average phosphorus concentrations for Basin S-5A and Basin S-7, adjusted for farm BMPs, are 0.187 and 0.094 mg/l, respectively. These long-term, basin-scale phosphorus concentrations represent the influent levels which must be treated to reduce the phosphorus concentrations to 0.05 mg/l in the water discharged from the EAA to the Water Conservation Areas (WCAs).

Table 2-2 Summary of Basin S-5A Flows/Loads

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Totals
Flow, unadjusted for BMPs											
cfs	136,688	128,660	78,636	183,589	156,156	138,253	114,099	131,331	130,160	115,843	1,313,415
MG	88,344	83,155	50,824	118,657	100,926	89,355	73,744	84,881	84,125	74,871	848,882
acre-ft	271,215	255,286	156,029	364,276	309,844	274,321	226,394	260,586	258,263	229,855	2,606,069
Phosphorus load, unadjusted for BMPs (kg)	49,694	63,379	47,418	104,571	95,262	82,140	50,883	41,415	44,025	63,026	641,813
Long-term average total phosphorus concentration, unadjusted for BMPs (mg/l)											0.200
Flow, adjusted for BMPs											
cfs	112,835	103,483	64,407	147,860	125,024	110,843	91,310	105,264	104,128	92,857	1,058,012
MG	72,927	66,883	41,627	95,565	80,805	71,640	59,015	68,034	67,300	60,015	683,811
acre-ft	223,887	205,329	127,796	293,383	248,072	219,935	181,177	208,865	206,610	184,247	2,099,301
Phosphorus load, adjusted for BMPs (kg)	39,158	47,736	36,515	78,675	71,485	61,693	38,171	31,116	33,018	47,374	484,941
Long-term average total phosphorus concentration, adjusted for BMPs (mg/l)											0.187[a]

[a] This is the long-term average total phosphorus concentration for Basin S-5A that will be reduced to 0.05 mg/l via the alternative technologies.

Table 2-3 Summary of Basin S-7 Flows/Loads

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Totals
Flow, adjusted for BMPs (b)											
cfs	147,041	86,384	44,579	116,160	139,040	163,847	153,703	119,110	75,860	112,959	1,158,684
MG	95,049	55,840	28,817	75,087	89,877	105,913	99,355	76,994	49,037	73,018	748,987
acre-ft	291,801	171,429	88,467	230,519	275,922	325,151	305,021	236,373	150,543	224,166	2,299,391
Load, adjusted for BMPs (kg)	20,120	19,256	13,266	39,693	22,335	36,358	28,291	39,118	12,033	36,474	266,945
Long-term average total phosphorus concentration, adjusted for BMPs (mg/l)											0.094[a]
Flow, unadjusted for BMPs[b]											
cfs	171,177	105,977	52,054	143,862	172,861	188,903	171,445	148,664	94,200	132,290	1,381,435
MG	110,651	68,505	33,648	92,994	111,741	122,109	110,824	96,098	60,892	85,514	892,977
acre-ft	339,698	210,310	103,300	285,492	343,044	374,875	340,230	295,022	186,939	262,528	2,741,439
Load, unadjusted for BMPs (kg)	24,404	25,362	17,021	52,665	29,595	44,499	33,673	52,114	15,922	46,535	341,790
Long-term average total phosphorus concentration, adjusted for BMPs (mg/l)											0.101

[a] This is the long-term average total phosphorus concentration for Basin S-7/S-150 that will be reduced to 0.05 mg/l via the alternative technologies.
[b] Also reflects adjustments eliminating cases where flow through the basin was greater than actual flow recorded leaving the basin.

Suspended Solids Concentrations

EAA runoff water TSS constitute a significant portion of the sludge produced during treatment by direct filtration or chemical treatment. A statistical analysis of the TSS information in the District's water quality data base was performed. The analysis indicated that the 50, 90, and 95th percentile TSS concentrations in Basin S-5A were 19, 40, and 58 mg/l, respectively. The corresponding TSS concentrations for Basin S-7 were 6, 14, and 16 mg/l, respectively. This analysis clearly shows Basin S-5A to exhibit higher TSS loadings.

Sizing Treatment Plants

Sizing of treatment units to accommodate all flows, including peak flows, could require construction of very large facilities whose full treatment capacities would be used infrequently. However, several strategies can be used to reduce treatment system size and capital cost. One approach treats a limited amount of flow to phosphorus levels below the treatment goal, bypassing the remainder of flow around the treatment unit. The treated and bypassed schemes are then recombined (i.e., blended back together). The split between treated and bypassed portions is arranged so that the phosphorus concentration of the recombined stream satisfies overall effluent phosphorus goal of 0.05 mg/l. A second approach is to provide flow equalization and balance the size of equalization and treatment facilities to arrive at a least-cost solution. Of course, both approaches (bypassing <u>and</u> flow equalization) can be used together.

Stormwater Treatment Areas (STAs) are designed to treat the entire flow. No bypassing or flow equalization will be used for these systems. In this report, the use of the bypass approach to evaluate direct filtration and chemical treatment has been chosen. It is recognized that flow equalization may have a place in development of the final basin-scale using combined treatment technology alternatives. For the present analysis, the more complicated calculations needed to define the mix of equalization and treatment capacities have been deferred until the choice of treatment alternatives becomes more clear cut.

Bypass calculations involved several steps. First, daily phosphorus loadings for Basins S-5A and S-7 were determined as the product of recorded daily flows and estimated daily phosphorus concentrations (adjusted for BMPs) over the 9.75-year period of record. The daily loads were then summed to produce the total load over the period of record. These sums are the BMP-adjusted numbers found in Tables 2-2 and 2-3.

The next step involved estimating the phosphorus load in the recombined effluent for a treatment plant of fixed flow capacity and phosphorus removal capability (expressed as a treated effluent phosphorus concentration). On any given day, basin flows less than or equal to plant treatment capacity would be treated, and flows in excess of the treatment capacity would be bypassed around the treatment plant. If all flow was less than the treatment capacity, the entire flow was assumed to be processed through the treatment plant. The daily recombined phosphorus loadings were then summed over the period of record, and the sum was expressed as a percentage of the untreated, adjusted basin phosphorus loadings. The value of 100 minus this percentage is the overall percentage removal. Figures 2-1 and 2-2 present families of curves for percentage of phosphorus removal versus required treatment plant capacity for various effluent phosphorus con-

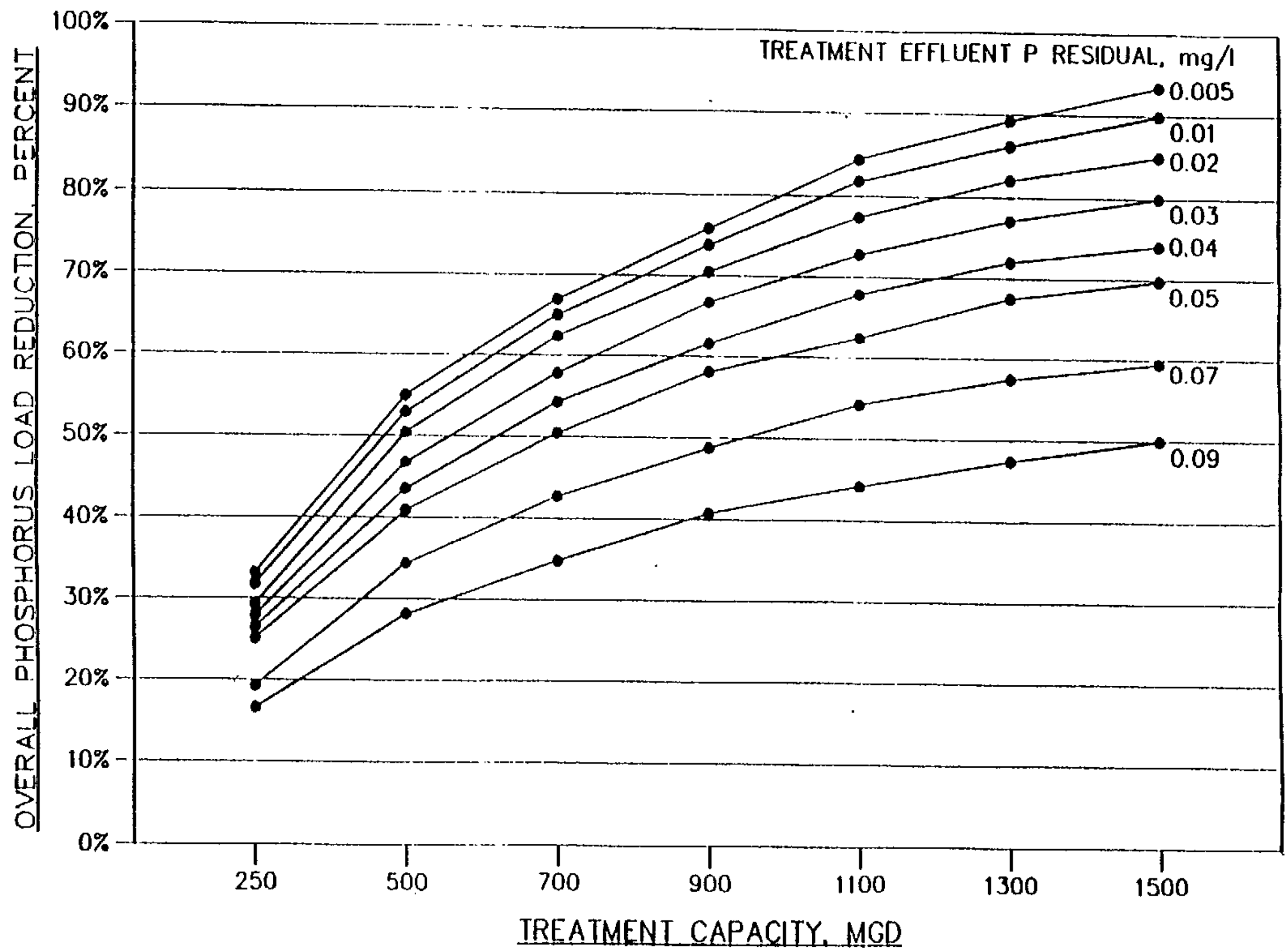

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FIGURE 2-1.
RELATIONSHIP OF TREATMENT CAPACITY AND EFFLUENT CONCENTRATION TO REDUCTION IN LOAD-BASIN S-5A

E:/7138/FIG2-1

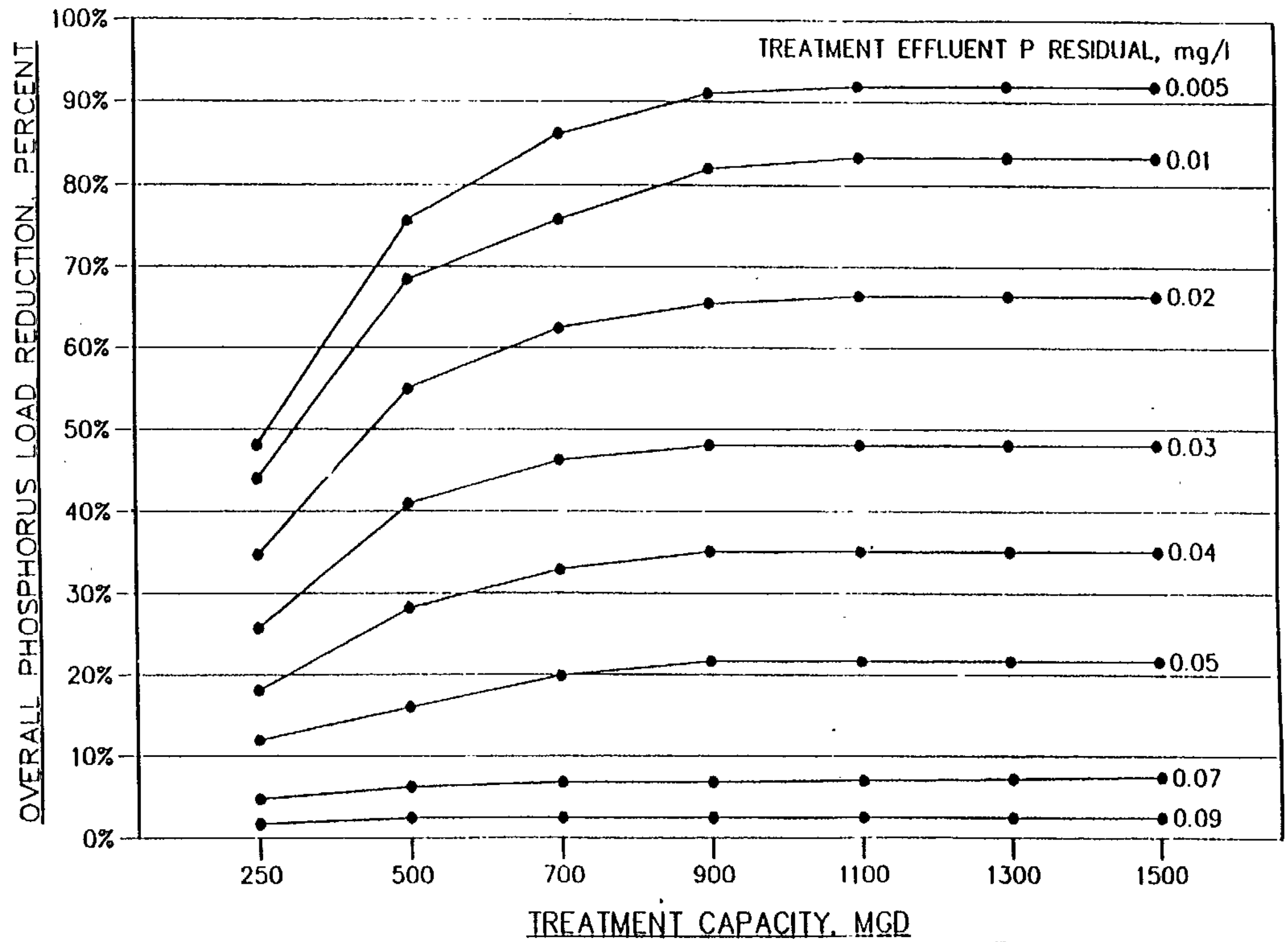

FIGURE 2-2.
RELATIONSHIP OF TREATMENT CAPACITY AND EFFLUENT CONCENTRATION TO REDUCTION IN LOAD-BASIN S-7

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E:/7138/FIG2-2

centrations. A fixed treatment plant flow capacity and fixed treatment plant effluent phosphorus concentration define one point on the curves of Figure 2-1 or Figure 2-2. The curves for each basin were developed by varying the treatment capacity and treated effluent phosphorus concentration.

As an example of use of the figures, consider Figure 2-1. Assume that a treatment technology (direct filtration, for example) reduces treated effluent phosphorus to 0.01 mg/l. The average Basin S-5A influent phosphorus concentration is 0.187 mg/l and the overall treatment phosphorus goal is 0.05 mg/l. The overall phosphorus removal requirement is therefore 73 percent. The treatment capacity (835 mgd) of the direct filtration plant needed to obtain the required overall 73 percent phosphorus removal can be found on the X-axis directly below the intersection of the horizontal line through 73 percent and the 0.01 mg/l phosphorus curve (0.01 mg/l being the treatment capability of direct filtration technology).

As indicated previously, the curves of Figure 2-1 and Figure 2-2 were developed assuming that BMPs reduced EAA phosphorus loads and flows by 25 and 20 percent, respectively. Different curves would be needed for other assumptions about BMP reductions. The calculations indicate that the required treatment plant capacities may be sensitive to assumptions about the magnitude of BMP adjustments. For example, if BMPs are assumed to reduce EAA phosphorus loads and flows by 45 and 40 percent respectively, the treatment plant would require only about one-fourth the 835-mgd capacity estimated above.

Table 2-4 summarizes our estimates for treatment technology phosphorus removal capabilities for all chemically oriented technologies in Basins S-5A and S-7. Influent phosphorus is assumed to be either initially in particulate form or to be converted to particulate phosphorus by precipitation or adsorption, except for a small dissolved phosphorus residual. Particulate phosphorus is assumed to be removed in the solids separation process in the same percentage as TSS. The phosphorus concentration after treatment is the sum of the dissolved residual and the remaining particulate phosphorus.

Table 2-4 Estimating Phosphorus Residuals in Effluents From Basin-Scale Treatment Units that Use Chemical Precipitants

Item	Basin S-5A		Basin S-7	
	Direct filtration	Chemical treatment	Direct filtration	Chemical treatment
Influent phosphorus, mg/l	0.187	0.187	0.094	0.094
Phosphorus, mg/l (after reaction but before solids separation)				
Dissolved phosphorus	0.005	0.005	0.005	0.005
Particulate phosphorus	0.182	0.182	0.089	0.089
Sum of influent phosphorus	0.187	0.187	0.094	0.094
Percent particulate phosphorus removed	97	80	97	80
Phosphorus, mg/l (after solids separation)				
Dissolved phosphorus	0.005	0.005	0.005	0.005
Particulate phosphorus	0.005	0.036	0.003	0.018
Sum of residual phosphorus	0.010	0.041	0.008	0.023

DIRECT FILTRATION

Filtration involves passage of solids-laden waters through one or more layers of granular media, typically coal, sand, or combinations thereof. During this passage, most of these solids are removed from the water and accumulated within a filter bed. When the bed storage capacity is exhausted, the bed is cleaned by washing the solids back out with air/water and water flushes. Normally, filtration is used as a polishing process after sedimentation, i.e., to remove those solids that escaped the sedimentation process.

Direct filtration does not include prior sedimentation. It is used when wastewater suspended solids and/or coagulant-generated chemical solids are in sufficiently low concentrations that bed storage capacity is not rapidly exhausted. Thus, longer filter runs are possible. The benefits of direct filtration are twofold. First, elimination of sedimentation saves space and reduces capital costs. Second, direct filtration systems require less coagulant than sedimentation systems, reducing chemical costs, sludge production, and the cost of treating and disposing of the sludge.

In some potential Everglades treatment scenarios, suspended solids concentrations are relatively high. For example, the 50 and 90 percent concentrations in Basin S-5A discharges are about 19 and 40 mg/l, respectively. The question naturally arises, "Is direct filtration appropriate for use in such instances?"

The literature is not clear about when direct filtration can be applied. One source indicates direct filtration is appropriate when suspended solids concentrations are below about 20 to 50 mg/l (Montgomery, 1985). McCormick and King, 1982, indicate that direct filtration can be used to achieve a turbidity goal of 0.1 NTU if influent turbidity is below 10 NTU, color is less than 15 units, and the algal clump count is below 1,000 units per ml. Wagner and Hudson, 1982, indicate that direct filtration is feasible if coagulant doses (alum, this case) are below 6 to 7 mg/l, but less feasible if coagulant doses are higher than 15 mg/l. The authors also indicate that problems arising from the need to process relatively high suspended solids loadings and coagulant doses can be overcome by designing a filter with more storage and capacity for greater loads.

Brown and Caldwell believes that this latter statement is correct, and that direct filtration can be applied on most surface water discharges from the EAA. This opinion is partially based on the Wahnbach Reservoir Plant, located near Bonn, Germany, which is an example where direct filtration is handling suspended solids concentrations as high or higher than concentrations expected in EAA discharges. Over the past 15 years, this 113-mgd capacity plant has consistently reduced phosphorus in agricultural stormwater runoff from 0.2 to about 0.005 mg/l (Clasen and Bernhardt, 1986; Bernhardt and Schell, 1982).

Process Description

Figure 2-3 presents the flowsheet for direct filtration as proposed for the Everglades project. The liquid-treatment process consists of chemical addition, rapid mixing, flocculation, and filtration. Waste backwash water, which is produced when the filters are cleaned, contains the process solid residues and is discharged to an earthen basin. The basin provides flow equalization and a place

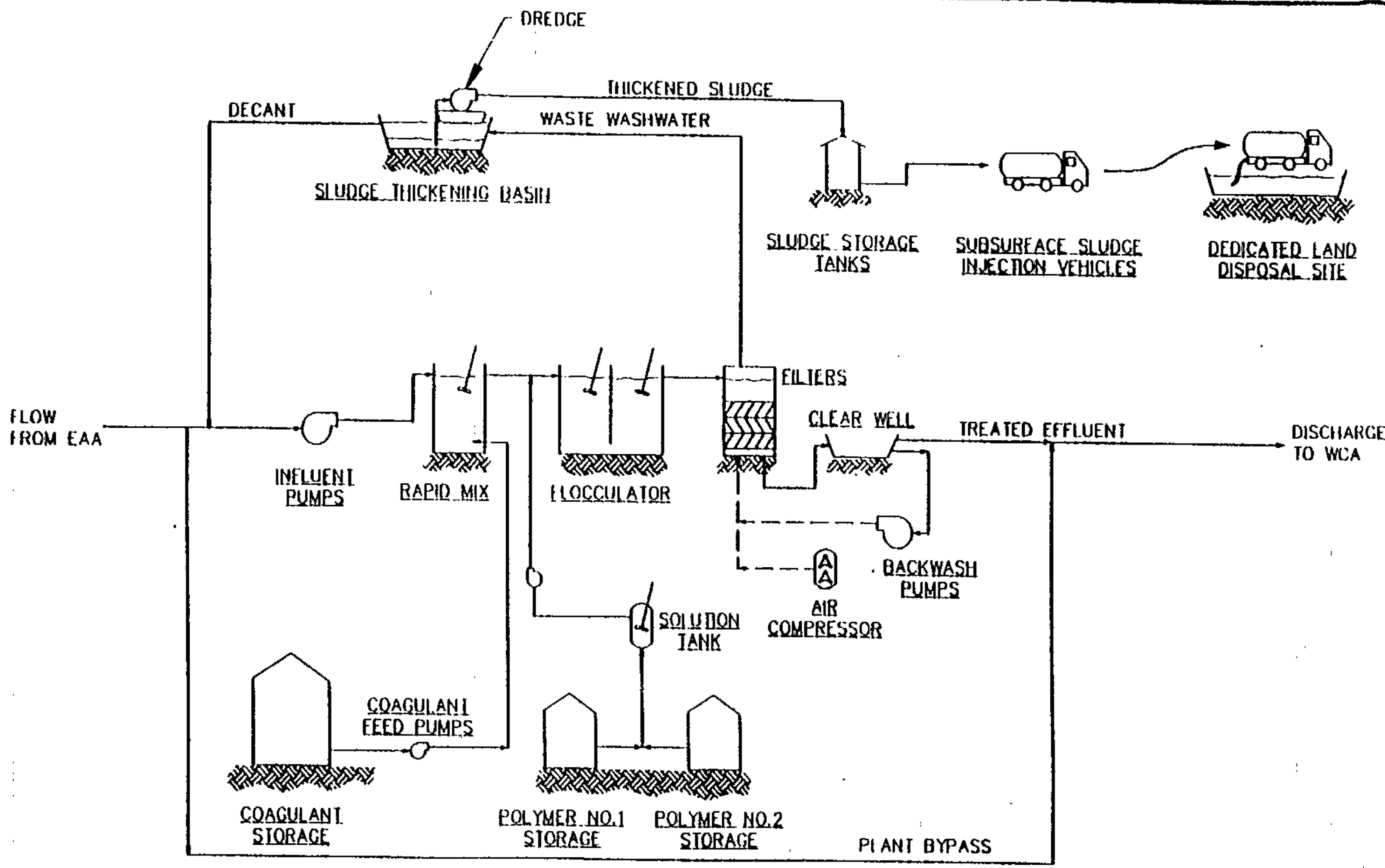

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FIGURE 2-3.
DIRECT FILTRATION FLOWSHEET

E:/7138/FIG2-3

for the solids to settle. Clear water near the basin water surface is decanted and recycled by gravity to the plant inflow canal. The solids (sludges) that settle to the bottom of the basin thicken by gravity to about 7 percent solids. The thickened sludge is removed from the bottom of the basin by a floating dredge and pumped to small sludge holding tanks.

In the preferred sludge disposal scenario, tank trucks take the sludge from the holding tanks and distribute it below the surface of a dedicated land disposal area, using specially designed plows equipped with hoses for subsurface sludge injection. Sludge dredging and disposal occurs only during dry months when the water in the sludge can be removed by evaporation. An alternative and more expensive sludge treatment and sludge disposal scenario involves dewatering of dredged sludge with plate-and-frame filter presses and disposal of dewatered sludge in a lined landfill. This more expensive alternative scenario would greatly reduce any environmental or permitting agency concerns about heavy metals buildup or percolation of water toward the groundwater table.

Table 2-5 provides the design basis for Basin S-5A and Basin S-7 filtration systems. Figures 2-4 and 2-5 are the site layouts for high- and low-rate direct filtration plants, respectively, for Basin S-5A. Figures 2-6 and 2-7 are similar site layouts for Basin S-7. The site layouts for Basin S-5A show the plant inflow waters coming from the L10/L12 borrow canal. Sampling will be required to confirm that phosphorus concentrations in this canal are representative of Basin S-5A as a whole. If not, the inflow channel would have to be relocated close to the existing Basin S-5A pump station. The same reasoning applies to Basin S-7. Figure 2-8 is a conceptual longitudinal cross-section of a direct filtration treatment plant showing the approximate elevations for the treatment units. The following sections discuss design rationale and design procedures used for the direct filtration systems.

Chemistry

Orthophosphate is the major form (but not the only form) of phosphorus in EAA drainage waters. The chemical basis for orthophosphate removal is fairly well understood. Discussions below center on orthophosphate removal mechanisms. Note that total phosphorus removal approximates ortho-phosphorus removal, but is not equal to it, because other phosphorus forms are removed to greater or lesser degrees. Therefore, total phosphorus removals in EAA waters may differ somewhat from total phosphorus removal in other systems, in part because of differing ratios of ortho-phosphorus to total phosphorus. Other factors which may affect transferability of results are differences in the concentration and nature of indigenous suspended solids, alkalinity, total dissolved solids, and dissolved organic carbon.

Treatment chemicals consist of precipitants/primary coagulants (called "coagulants" hereafter), pH adjustment chemicals, and secondary coagulants.

Primary Coagulants. Several primary coagulants were considered.

1. **Iron Salts.** The most common commercially available iron coagulants are ferric chloride, ferric sulfate, ferrous chloride, and ferrous sulfate. All have been used to remove phosphorus from municipal and industrial wastewaters. Pickle liquor, a waste product of the steel industry which contains ferrous iron, also has been used successfully.

Table 2-5 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Basin data		
Plant flow, million gals		
Maximum annual	95,565	105,913
Minimum annual	41,627	28,817
Average annual	70,134	76,819
Phosphorus concentration, mg/l		
Maximum annual	0.234	0.140
Minimum annual	0.121	0.056
Average	0.187	0.094
TSS concentration, mg/l		
50th percentile	19	6
90th percentile	40	14
95th percentile	58	16
Plant data		
Percent of days on-line	33	71
Flow, mgd		
Maximum	835	220
Minimum	0	0
Average		
All days	148	110
When operating	451	155
Maximum year		
Average all days	192	151
When operating	584	213
Influent pumps		
Number of small pumps	1	1
Capacity each small pump, gpm	30,000	30,000
Peak plant flow, mgd	835	220
Number of large pumps	5	3
Capacity each large pump, gpm	138,000	62,000
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33 percent $FeCl_3$	Liquid, 33 percent $FeCl_3$
Dose, as Fe, mg/l		
Average	5.7	5.7
Maximum	10	10
Pumps		
Number (1 spare)	5	2
Capacity, each, gpm	10	10
Storage tank		
Volume, gals	740,000	195,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2

Table 2-5 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Polymer No. 1		
Form	Liquid, slightly cationic	Liquid, slightly cationic
Dose, mg/l		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	5	2
Capacity, each, gpm	1.4	1.5
Solution tank volume, gals	10,000	2,600
Storage tank		
Volume, gals	2,500	600
Storage at peak feed rates, wks	2	2
Polymer No. 2		
Form	Liquid, slightly cationic	Liquid, slightly cationic
Dose, mg/l		
Average	0.5	0.5
Maximum	1.0	1.0
Pumps		
Number (1 spare)	5	2
Capacity, each, gpm	7.0	7.4
Solution tank volume, gals	50,000	13,000
Storage tank		
Volume, gals	11,000	3,000
Storage at peak feed rates, wks	2	2
Rapid mix tanks		
Number, in parallel	4	1
Volume, each, gals	4,800	5,100
Detention time at peak plant flow, sec	2	2
Velocity gradient, sec^{-1}	750	750
Power input per tank, HP	20	20
Material of construction	Concrete	Concrete
Flocculators		
Number, in parallel	4	1
Stages per flocculator	2	2
Volume per stage, gal	218,000	229,000
Detention time per stage at peak flow, mins	1.5	1.5
Velocity gradient, sec^{-1}		
Maximum	50	50
Minimum	110	110
Power input per tank, HP	20	20
Material of construction	Concrete	Concrete

Table 2-5 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Filters (low rate)		
Number, in parallel	80	20
Surface area per bed, ft^2	1,385	1,379
Material of construction	Concrete	Concrete
Width x length, ft	24 x 58	24 x 57
Filter rate, gpm/ft^2		
Maximum	6	6
Average, when operating	2.8	3.9
Solids load, $lb/day.ft^2$		
Maximum	4.5	2.0
Average, when operating	1.0	0.9
Filters (high rate)		
Number, in parallel	48	12
Surface area per filter, ft^2	1,324	1,303
Material of construction	Concrete	Concrete
Width x length, ft	24 x 55	24 x 54
Filter rate, gpm/ft^2		
Maximum	11	11
Average, when operating	4.7	6.9
Solids load, $lb/day.ft^2$		
Maximum	7.8	3.6
Average, when operating	1.9	1.6
Filter Media		
Top layer		
Material	Activated carbon	Activated carbon
Effective size, mm	3.3	3.3
Uniformity coefficient	1.46	1.46
Depth, in	14	14
Middle layer		
Material	Anthracite	Anthracite
Effective size, mm	1.73	1.73
Uniformity coefficient	1.32	1.32
Depth, in	57	57
Bottom layer		
Material	Quartz sand	Quartz sand
Effective size, mm	0.87	0.87
Uniformity coefficient	1.28	1.28
Depth, in	24	24
Available headloss increase, ft	7	7
Method of flow control	Rate of flow control valve	Rate of flow control valve
Underdrain	Block	Block

Table 2-5 Basis of Design for Direct Filtration (continued)

Item	Basin S-5A	Basin S-7
Backwash system		
Backwash reservoir (clear well)		
Number, in parallel	1	1
Volume, each, gals	250,000	250,000
Depth, ft	10	10
Surface area, acres	0.08	0.08
Material of construction	Concrete	Concrete
Backwash		
Maximum rate, gpm/ft^2	31	31
Number of pumps	12	4
Capacity, each, gpm	23,000	23,000
Air Scour		
Rate, scfm/ft^2	4	4
Number of compressors	4	1
Capacity, each, scfm	5,200	5,200
Washwater reclamation basin/thickener		
Volume, million gals	57	27
Depth, ft	15	15
Surface area, acres	11.7	5.5
Reclaimed washwater pumps		
Number (1 spare)	5	2
Capacity, each, gpm	6,300	6,300
Number of dredges	1	1
Capacity each dredge, gpm	1,000	500
Concentration of dredged sludge, percent	5	5
Material of construction	Earth	Earth
Dedicated land disposal		
Sludge production, tons dry solids per year		
Maximum	9,537	4,539
Average	7,357	3,306
Maximum application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	7	3
Area per section, acres	48	53
Number of sludge storage tanks	7	3
Volume each sludge storage tank, gals	7,500	7,500
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	2	1
Spreading capacity each, gal/day	120,000	120,000
Land requirements, acres		
Low-rate filters	424	186
High-rate filters	423	185

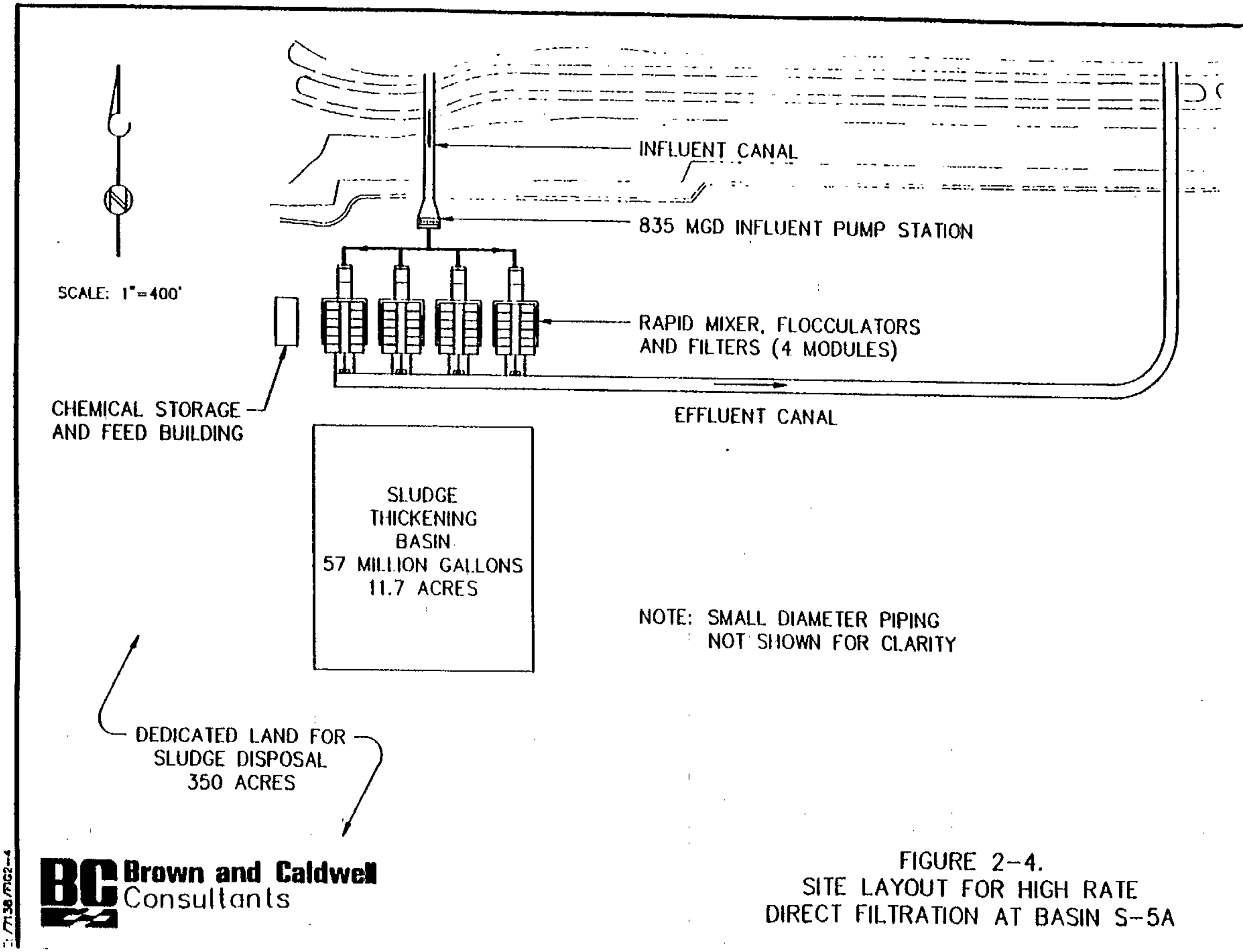

FIGURE 2-4.
SITE LAYOUT FOR HIGH RATE
DIRECT FILTRATION AT BASIN S-5A

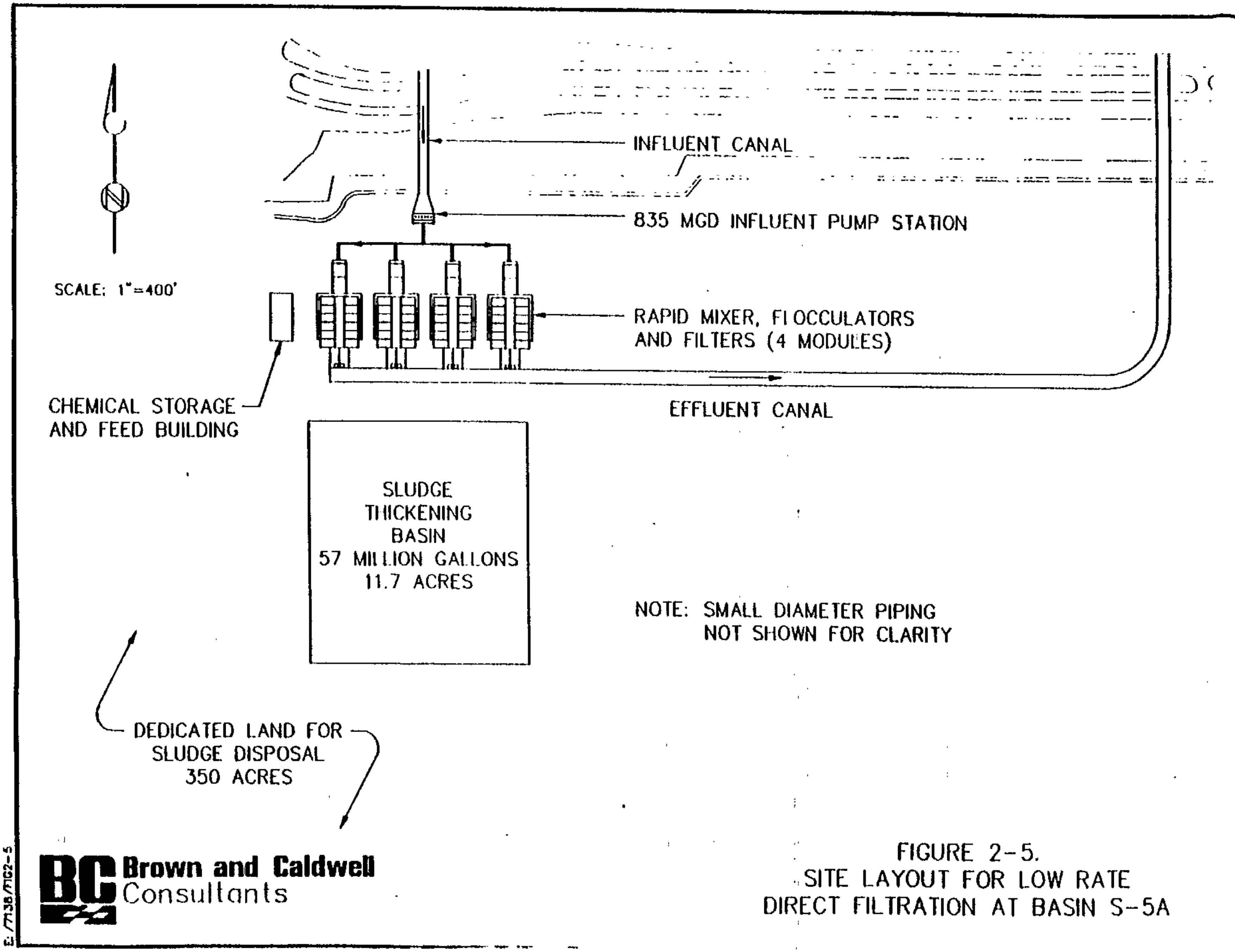

FIGURE 2-5.
SITE LAYOUT FOR LOW RATE
DIRECT FILTRATION AT BASIN S-5A

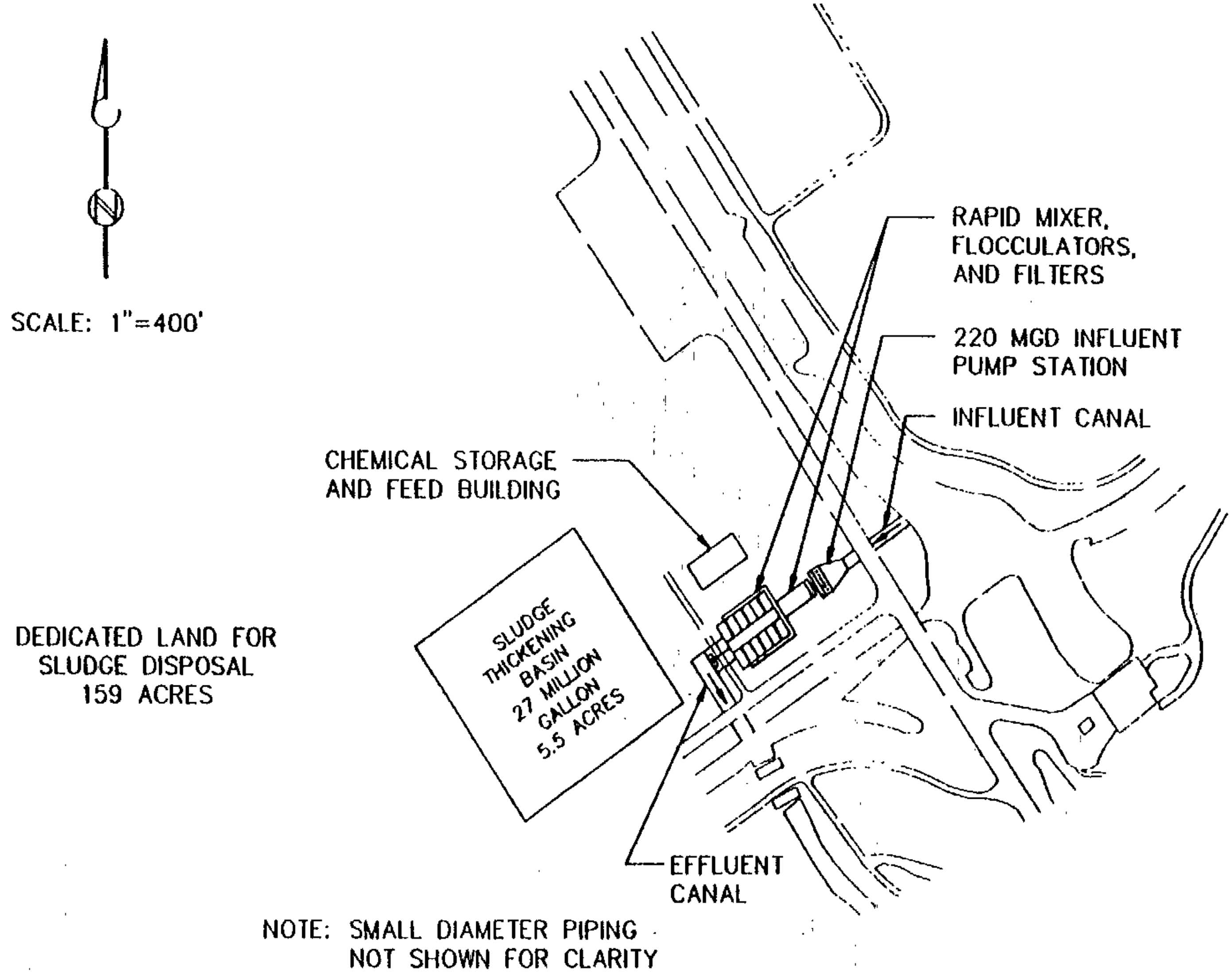

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FIGURE 2-6.
SITE LAYOUT FOR HIGH RATE
DIRECT FILTRATION AT BASIN S-7

E:/7138/FIG2-6

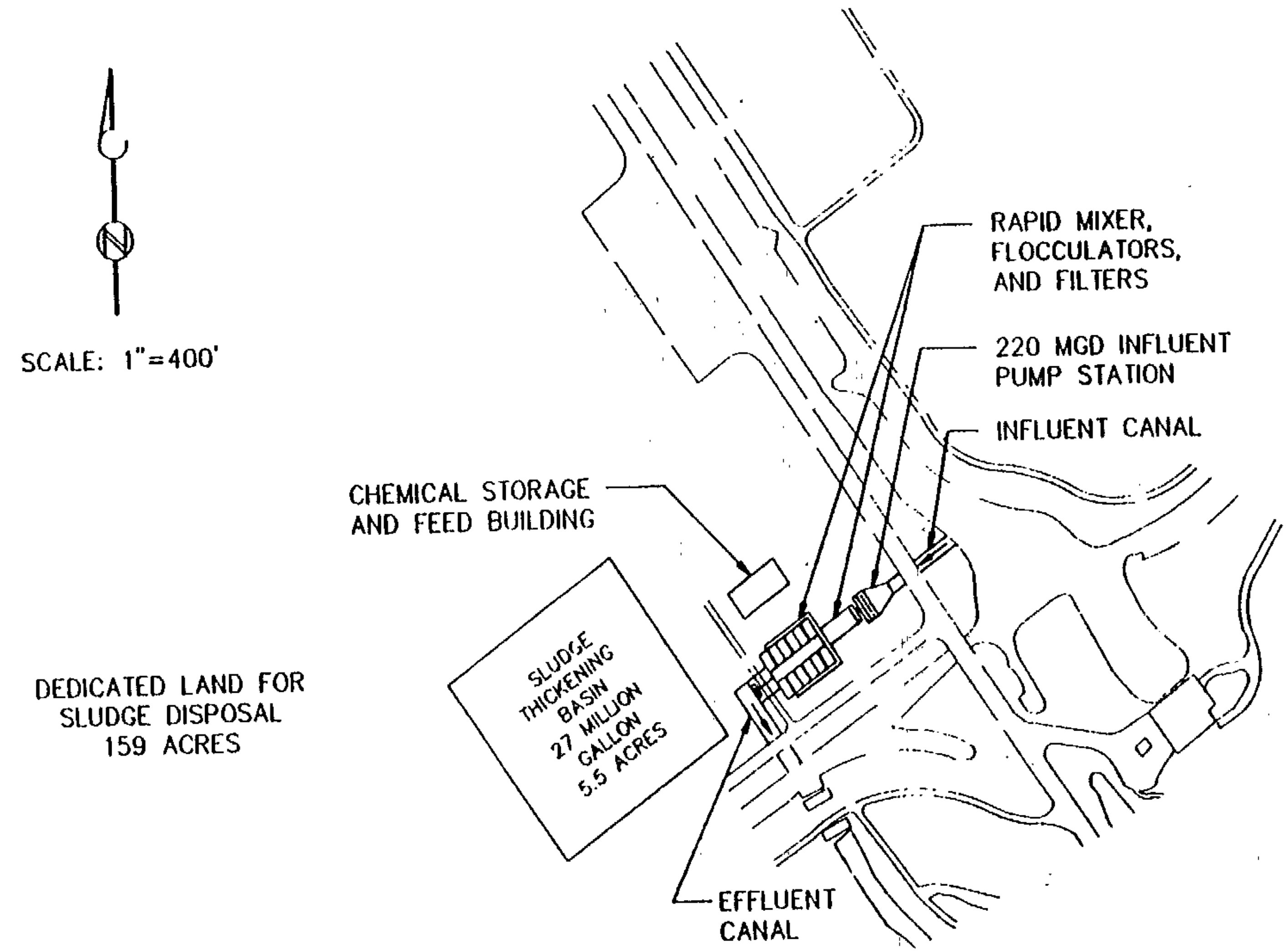

FIGURE 2-7.
SITE LAYOUT FOR LOW RATE
DIRECT FILTRATION AT BASIN S-7

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7138/FIG2-7

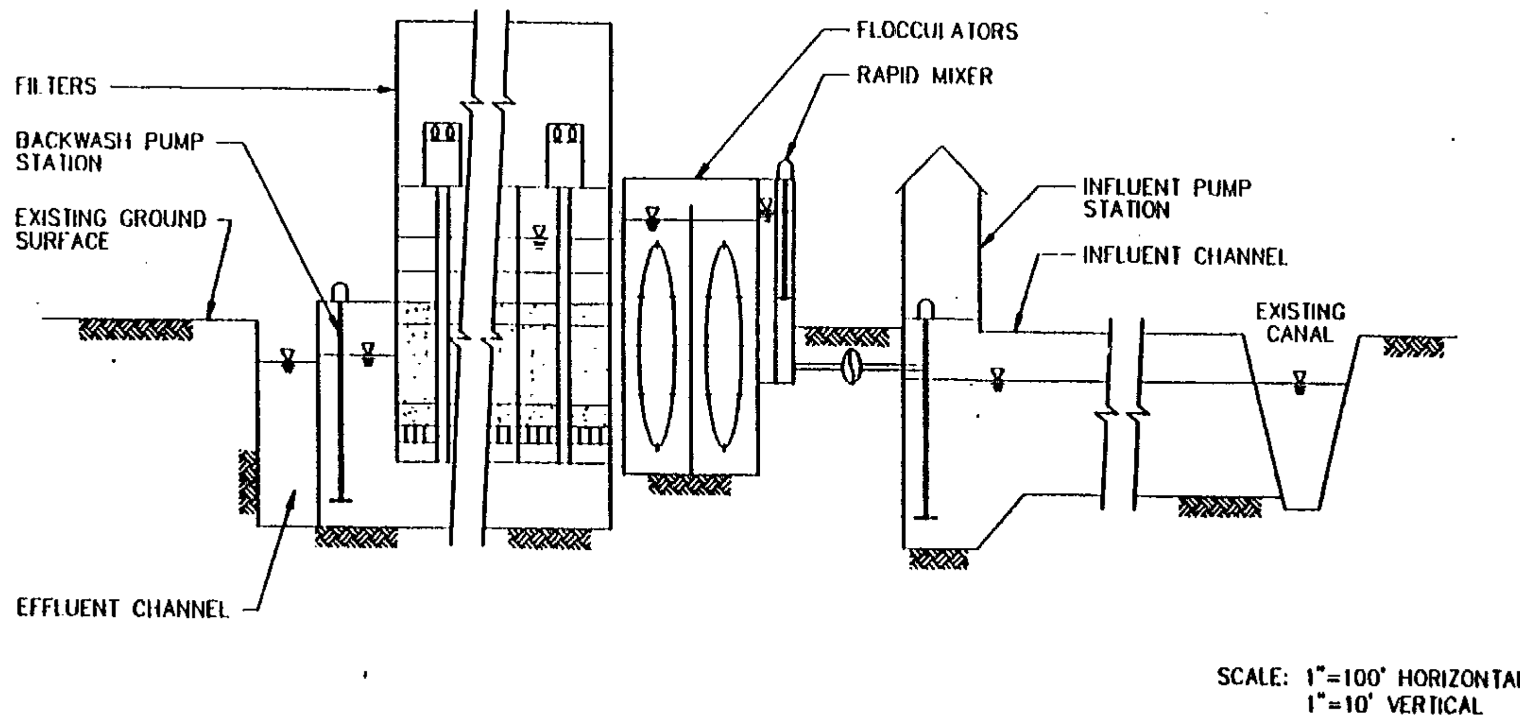

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FIGURE 2-8.
CONCEPTUAL LONGITUDINAL
SECTION, DIRECT FILTRATION

E:/7138/FIG2-8

If the initial phosphorus concentration is above about 1 mg/l, as it is for most municipal wastewaters and many industrial wastewaters, addition of iron precipitates phosphorus stoichiometrically:

$$n\ Fe^{+3} + PO_4^{-3} + 3\ (n - 1)\ H_2O = Fe_nPO_4(OH)_{3(n-1)} + 3\ (n - 1)\ H^+ \qquad (2\text{-}1)$$

"Stoichiometric" means that the ratio of iron to phosphorus in the precipitated solids is constant. The value of n is estimated to be about 1.6 (Gates, et al., 1990).

Once the phosphorus concentration has been reduced to below about 1 mg/l, or if phosphorus is initially below about 1 mg/l (as it is in EAA drainage waters), different phosphorus removal mechanisms take over. The amount of $Fe_nPO_4(OH)_{3(n-1)}$ that can be precipitated is limited by the very small amount of phosphorus available, and the rate of phosphorus precipitation reduces sharply. In this case, most of the iron added reacts with water to form solid iron hydroxide:

$$Fe^{+3} + 3\ H_2O = Fe(OH)_3 + 3\ H^+ \qquad (2\text{-}2)$$

$Fe(OH)_3$ precipitation both enhances and hinders phosphorus removal. It enhances phosphorus removal by providing additional solid surfaces to adsorb phosphorus. Thus phosphorus removal by sorption is superimposed on phosphorus removal by precipitation. $Fe(OH)_3$ precipitation hinders phosphorus removal by consuming Fe^{+3} ions, thus reducing the driving force for phosphorus precipitation. The iron/phosphorus molar ratio is much higher (8 to 25) in this low phosphorus range of operations than it is when stoichiometry controls.

The phosphorus residual is most strongly affected by the ratio of Fe added to initial phosphorus and pH. The latter parameter is especially important when the iron/phosphorus molar ratio is high. Calculations suggest that phosphorus residuals are reduced to lowest values at a pH of about 5.0 (Stumm and Morgan, 1970). However, the Wahnbach Reservoir treatment plant obtains very low phosphorus residuals (<0.005 mg/l) at pH values in the range of 6 to 6.5 (Bernhardt, 1992).

Iron hydroxide and the transition species $Fe(OH)_2^+$, $Fe_2(OH)_2^{+4}$, and $Fe(OH)_2^+$ which form in the time between iron addition and full precipitation of iron hydroxide also serve another purpose. The iron solids and indigenous drainage solids tend to be small (i.e., colloidal) and thus not readily separated from the water by conventional treatment techniques (sedimentation and filtration). These processes work better with larger solids. Larger solids are obtained by combining the smaller solids into agglomerates (floc) in a two-stage process.

a. **Destabilization.** In this step, the forces which tend to keep the small particles apart are removed, reduced, or overcome. The particles may not coalesce in their native states for several reasons. They generally are negatively charged and repel one another (like charges repel). Their structures may also be such that they cannot approach one another closely (stearic hindrance). Layers of bound water also may prevent close approach.

Electrostatic repulsion can be reduced or eliminated when the positively charged transition species adsorb onto the negatively charged colloids. The resulting electrically neutral agglomerates can then approach one another, allowing short-range attractive forces to establish weak interparticle linkages.

If the solids particle concentration is very low, or the particles are separated by stearic hindrance or bound water, destabilization by adsorption/charge neutralization will not be effective. In such instances, iron in excess of that required for phosphorus precipitation and adsorption/charge neutralization must be added to promote formation of relatively large volumes of iron hydroxide floc. The floc is voluminous and envelopes the phosphorus precipitates and indigenous solids, sweeping them along with it when it is removed. Note that destabilization can also occur with "bridging" mechanisms (see Polymers, below).

b. **Flocculation.** Once the particles have been destabilized, they are brought into contact by gentle mixing. The particles stick together, becoming larger in size and fewer in number. Sufficient flocculation time is provided to allow floc to grow to readily separable size.

Destabilization is carried out in the rapid mix system, as is phosphorus precipitation. Flocculation is carried out in the flocculators. The solid particles remain in suspension throughout the destabilization and flocculation processes.

2. **Alum.** The phosphate precipitation and solids destabilization mechanisms for alum ($Al_2(SO_4)_3 \cdot 14\ H_2O$) are similar to those for iron. Reactions 2-3 and 2-4 below, are analogous to Reactions 2-1 and 2-2, above.

$$n\ Al^{+3} + PO_4^{-3} + 3(n-1)\ H_2O = Al_nPO_4(OH)_{3(n-1)} + 3(n-1)\ H^+ \qquad (2\text{-}3)$$

Different n values have been reported, ranging from 0.8 to 1.9, with the most common value being 1.4. Phosphate precipitation is favored at a pH of approximately 6 (Stumm and Morgan, 1970).

$$Al^{+3} + 3\ H_2O = Al(OH)_3 + 3\ H^+ \qquad (2\text{-}4)$$

3. **Lime.** Equations 2-5, 2-6, and 2-7 describe the major reactions of lime with wastewater. A major phosphorus removal mechanism is precipitation as calcium phosphate. In relatively uncontaminated waters, such as EAA drainage, the solid compound is likely to be calcium hydroxyapatite.

$$5\ Ca(OH)_2 + 3\ HPO_4^- = Ca_5(PO_4)_3OH + 3\ H_2O + 2\ OH^- \qquad (2\text{-}5)$$

Phosphorus removals increase as more lime is added and the pH increases. There is no optimum pH range as there is for iron or alum precipitation. Calculations suggest that a pH as low as 9.0 is sufficient to obtain the low phosphorus residuals needed in the EAA.

Much lime can be consumed by the reaction of lime and bicarbonate, a major runoff water component. The product of this reaction is calcium carbonate; if raw water bicarbonate concentrations are high, chemical sludge production can also be high. Calcium carbonate can adsorb a limited amount of phosphorus.

$$Ca(OH)_2 + HCO_3^- = CaCO_3 + H_2O + OH^- \qquad (2\text{-}6)$$

Calcium phosphate, calcium carbonate, and indigenous wastewater solids must be destabilized. Magnesium hydroxide, precipitated at pH values above approximately 10, provides a sweep mechanism in the lime system, similar to those provided by iron hydroxide and aluminum hydroxides in the iron and alum systems, respectively. Some phosphorus also can be adsorbed on magnesium hydroxide.

$$Ca(OH)_2 + Mg^{+2} = Mg(OH)_2 + Ca^{+2} \qquad (2\text{-}7)$$

If the wastewater is deficient in magnesium, or if the reaction is to be carried out at pH values below 10 (to minimize lime consumption and chemical sludge production), small amounts of iron or alum can be added to the wastewater to perform the destabilization function.

The following text discusses the strengths and shortcomings of the primary precipitants/ coagulants:

1. **Ability to Achieve Phosphorus Reduction Goals.** Ferric salts have demonstrated the ability to consistently remove phosphorus to low levels in a direct filtration system at the Wahnbach Reservoir Plant. The Wahnbach Reservoir Plant treats up to 113 million gallons per day (mgd) of stormwater runoff, reducing phosphorus from above 0.2 mg/l to about 0.005 mg/l with an addition of 3 to 10 mg/l of ferric iron. This plant has been in operation since 1977. Table 2-6 summarizes design and operating data for the Wahnbach Reservoir Plant.

   The Hochdorf Treatment Plant near Lake Baldegg in Switzerland uses 3 to 4 mg/l of ferric iron and direct filtration to reduce phosphorus in effluent from an activated sludge system from about 1 mg/l to 0.15 mg/l (Boller, 1984). Pilot tests showed that phosphorus residuals of 0.005 mg/l could be obtained with iron doses in the range of 10 to 15 mg/l. The full-scale plant has been in operation since 1979. Hochdorf plant data also are summarized in Table 2-6.

Table 2-6 Salient Features of the Wahnbach Reservoir and Hochdorf Filter Systems

Item	Wahnbach Reservoir	Hochdorf
Flow, mgd		
Average	N/A	2.3
Maximum	113	5.8
Chemicals		
Primary coagulant, mg/L	Fe^{+3}, 3-10	Fe^{+3}, 3-4
Filtration aid, mg/L	Cationic, 0.1	0.2
Rapid mix		
Device	Pipeline	Open-channel venturi
G, sec^{-1}	640 to 750	N/K
t, sec	20	N/K
Gt	12,800	N/K
Flocculator		
Number of cells	2 in series	1
G, sec^{-1}	Variable	N/K
t, sec	180	25
Gt	20,000 to 50,000	N/K
Mixers	Mechanical	None
Filters		
Number of cells	10	6
Area per cell, ft^2	1,291	64
Filter rate, gpm/ft^2		
Average	N/A	4.1
Maximum	6.1	10.2
Media configuration		
Layer 1		
Material	Activated carbon	Expanded slate
Depth, ft	1.2	6
Particle diameter, mm	3 to 5	2 to 4
Layer 2		
Material	Anthracite	Sand
Depth, ft	4.9	1.2
Particle diameter, mm	1.5 to 2.5	0.8 to 1.2
Layer 3		
Material	Sand	---
Depth, ft	2	---
Particle diameter, mm	0.7 to 1.2	---

Table 2-6 Salient Features of the Wahnbach Reservoir and Hochdorf Filter Systems (continued)

Item	Wahnbach Reservoir	Hochdorf
Filter type	Gravity	Pressure
Terminal headloss, ft H_2O	N/K	19.7
Estimated specific solids capture (lb/ft^2 surface area)		
At 6 gpm/ft^2, 50 mg/L TSS	1.4	---
At 8.2 gpm/ft^2	---	0.64
Media cleaning		
Air scour alone, cfm/ft^2	4.1	3.8
Backwash alone, gpm/ft^2	30.7	28.6
Air scour/backwash combined		
Air scour, cfm/ft^2	N/A	3.8
Backwash, gpm/ft^2	N/A	6.1
Backwash, percent of filter feed	3	N/K
Performance (at average conditions)		
Phosphorus		
Influent, mg/L	0.200	1.1
Effluent, mg/L	0.005	0.14
Percent removal	98	87
TSS		
Influent, mg/L	N/K	12
Effluent, mg/L	N/K	2.3
Percent removal	N/K	81
Algae, as chlorophyll		
Influent, g/L	25	N/A
Effluent, g/L	1.3	N/A
Percent removal	95	N/A
Turbidity		
Influent, FTU	10	N/K
Effluent, FTU	0.06	N/K
Percent removal	99.3	N/K

mgd = million gallons per day
N/A = not applicable
mg/L = milligrams per liter
N/K = not known
ft^2 = square foot
gpm/ft^2 = gallons per minute per square foot
ft = foot
mm = millimeters
lb = pound
TSS = total suspended solids
cfm/ft^2 = cubic feet per minute/square foot of filter plan area
FTU = formation turbidity units

Additionally, Dr. David Anderson, 1992, of the University of Florida has conducted jar tests with EAA runoff. In verbal communications with Dr. Anderson, he has indicated phosphorus reductions to levels as low as 0.001 to 0.002 mg/l with iron salts. These results are important because they demonstrate that EAA runoff (which may differ from the Wahnbach Reservoir and Hochdorf wastewaters in important ways) can be effectively treated with iron salts.

Full-scale testing at two Washington County, Oregon municipal wastewater treatment plants suggests alum is capable of producing low phosphorus residuals (Richwine et al., no date; Hemphill et al., 1990). In both treatment plants, phosphorus is removed in the primary system by alum precipitation, in the secondary system by biological uptake, and in the tertiary system by alum precipitation. Tertiary results appear to be most applicable to the Everglades project. The tertiary systems consisted of alum addition, clarification, and filtration. The tertiary system at the Rock Creek plant reduced phosphorus from 0.163 to 0.03 mg/l in 1990 and from 0.078 to 0.013 mg/l in 1991 (average values). The Rock Creek staff used an Al/phosphorus molar ratio of 15:1. The tertiary system at the Durham plant reduced phosphorus from 0.21 to 0.04 mg/l, from 0.39 to 0.05 mg/l, and from 0.83 to 0.12 mg/l during three test programs conducted in 1989. The Durham alum dose was 40 mg/l in all cases.

The calculations suggest that lime treatment can reduce phosphorus to less than 0.01 mg/l at pH 9.0, providing hydroxyapatite is the solid controlling phosphorus solubility. Jar and pilot tests at the Rock Creek plant indicated "very low" phosphorus residuals were obtained with single-stage lime treatment.

2. **Operability.** General experience indicates that iron is an effective destabilant over a much wider pH range than alum, i.e., alum is much less forgiving than iron when swings from the pH set point are experienced. Alum and iron dissolve easily (and in fact can be delivered as liquids), and their solutions are easy to pump. Lime is a dusty, abrasive, dry chemical, which must be mixed with water and injected as a slurry. The slurry has a pronounced tendency to plug pumps and pipelines.

3. **Cost.** Table 2-7 shows chemical costs for iron, alum, and lime systems designed to achieve phosphorus residuals of 0.005 mg/l or less in Basin S-5A water. Iron is the least-cost chemical. Iron costs are based upon the du Pont Company's best estimate of price for the year 1997 (du Pont, 1992). Note that du Pont's estimate (18 cents per pound of iron) is about 40 percent of a second supplier (Boliden Intertrade, formerly the Tennessee Chemical Company). Boliden Intertrade's estimate was about 45 cents per pound of iron (Boliden Intertrade, 1992). The du Pont Company can apparently provide a very favorable rate because its ferric chloride is a waste material (a by-product of paint manufacturing). They sell it cheaply rather than throw it away and pay disposal costs.

Table 2-7 Comparison of Chemical Dose, Chemical Cost and Sludge Production for Various Treatments of Basin S-5A Water

Item	$FeCl_3$	Alum	Lime (CaO)
Dose, mg/l	17	27	115
Chemical cost, dollars per pound[a]	0.063	0.064	0.023
Chemical cost, dollars per million gallons	8.9	14.3	22.0
Chemical sludge production, mg/L			
$Fe_{1.6}PO_4(OH)_{1.8}$	0.9	---	---
$Fe(OH)_3$	10.1	---	---
$Al_{1.4}PO_4(OH)_{1.2}$	---	0.7	---
$Al(OH)_3$	---	6.1	---
$Ca_5(PO_4)_3OH$	---	---	1
$CaCO_3$	---	---	312
Bound water	2.5	1.5	---
Sum	13.5	8.3	313

[a] Iron price from the du Pont Company, Wilmington, Delaware. Alum price from the General Chemical Company, Tampa, Florida. Lime price is from the Chemical Marketing Reporter, June 28, 1991.

4. **Availability.** The du Pont and Boliden Intertrade Companies have indicated that they can provide ferric salts to the Everglades project in the quantities needed. The du Pont Company is the world's largest manufacture of ferric chloride. Company sales representatives indicate that ferric chloride could be shipped by barge from the company's manufacturing site in Delaware, and transported by trucks for shipment to the treatment plants. Boliden Intertrade produces ferric oxide at its mine in Tennessee. Boliden sales representatives indicated the iron ore could be shipped to Florida by rail, then converted to ferric sulfate locally by acidification with sulfuric acid.

   Alum can be supplied in the quantities needed by the General Chemical Company of Tampa, Florida (General Chemical, 1993). General Chemical marketing representatives did not indicate the geographical source of their alum.

5. **Sludge Production.** Table 2-7 clearly shows that iron and alum produce far fewer chemical solids than lime. Lower solids production equates to longer filter runs (hence higher filter productivity) and lower sludge treatment and disposal costs.

6. **Water Quality Effects.** Alum and iron treatments will have rather small impacts on non-phosphorus related water quality. Minimal changes occur because direct filtration uses very low coagulant dosages.

   Total dissolved solids (TDS) will increase slightly due to addition of the reagent counter-ions (chloride for ferric chloride, sulfate for alum). Ferric chloride treatment would increase chloride and TDS concentrations by about 9 mg/l in Basin S-5A and 6 mg/l in Basin S-7, on the average. Alum treatment would increase sulfate and TDS levels by about 10 mg/l in Basin S-5A and 7 mg/l in Basin S-7. These additions would not cause violations of Florida Class I (potable water supply) or Class III (recreation, fish, and wildlife) chloride water quality standards. There are no Class I or Class III sulfate water quality standards. Alkalinity will be reduced marginally by iron and alum treatment (10 to 20 mg/l, as $CaCO_3$), and significantly by lime treatment (about 100 mg/l, as $CaCO_3$). However, alkalinity is not in danger of falling below water quality standards (20 mg/l, as $CaCO_3$) with the use of any of these chemical.

TDS is the only parameter expected to exceed water quality standards, and that will occur only because TDS is already well above the Class I standard (500 mg/l) in the untreated water. Note that lime treatment can reduce TDS concentrations by about 25 percent. This reduction is not sufficient to satisfy Class I water quality standards, however.

Treatment will reduce the concentrations of some heavy metals, notably cadmium and zinc, which are now close to or above Class I water quality standards. Addition of iron or alum coagulants should not increase iron or aluminum concentrations. Rather, treatment should reduce their concentrations. This result accrues because indigenous metals and reagent metals are converted to particulate form during treatment, and particulates are virtually removed in the filters.

Table A-1, Appendix A, estimates changes in concentrations of regulated parameters expected to be induced by direct filtration when ferric chloride is used as the primary coagulant. It then compares the resultant concentrations of regulated parameters with FDER water quality limits for Class I and Class III water bodies.

The apparent best primary coagulants are ferric chloride and alum. Lime is not practical for direct filtration because its high chemical solids production will overload the filters and result in high sludge treatment and disposal costs. The conceptual design has been based on the use of ferric chloride, primarily because of its lower purchase price and proven ability to reduce phosphorus in EAA waters to very low concentrations. However, alum should not be dismissed as a candidate chemical, since it may be able to achieve equally low phosphorus residuals and has the advantage of apparently lower sludge production. Experiments (jar tests) to more clearly define the relative merits of these two chemicals are in order.

pH-Adjustment Chemicals. Acid generated by iron or alum addition tends to depress system pH, in some instances carrying it below the pH range optimum for phosphorus precipitation and solids destabilization. Alternatively, insufficient acid may be generated, leaving the pH above the optimum range. Lime or caustic soda (NaOH) can be added concurrent with alum or iron to prevent the pH from dropping below the optimum range. Acid (typically sulfuric acid [H_2SO_4]) or carbon dioxide (CO_2) can be used to drive the pH down into the optimum range.

The Wahnbach Reservoir and Hochdorf systems do not appear to use pH adjustment chemicals. Either the optimum pH values are achieved without pH adjustment chemicals (i.e., by iron addition alone) or else the benefits achieved by pH optimization are not worth the cost of optimizing. In this analysis, we assume no pH adjustment chemicals are needed. This assumption should be verified during bench-scale experiments designed to locate optimum process pH conditions.

__Polymers.__ Polymers are also destabilizing agents. Positively charged (cationic) polymers may reduce electronegative repulsive forces by charge neutralization. "Bridging" is another destabilization method. Active sites along a long-chain polymer attach to several different colloidal particles. The polymer acts as a bridge connecting these small particles, forming a larger and much stronger agglomerate. Oddly, attachment between negatively charged colloids and active sites can occur even when the active sites are neutral or even electronegative. In such cases, the chemical attraction between active sites and colloids is sufficiently strong to provide the attachment and even overcome electrostatic repulsion.

Polymers are often used in conjunction with primary coagulants. As described previously, the coagulants allow small individual particles to come together to form somewhat loose, diffuse floc. The polymers further gather these agglomerates and increase their strength. Increasing floc strength allows floc to remain intact (and thus readily separable) during subsequent downstream processing. The Wahnbach Reservoir plant uses a slightly cationic (positively charged) polymer in the winter (in conjunction with iron treatment) to help neutralize the negative charge of the feedwater solids. In the summer, when the feedwater contains high concentrations of negatively charged algae, a strongly cationic polymer is used in place of the slightly cationic polymer.

It is assumed that one or more polymers will be used during direct filtration operations. General experience indicates that polymer addition is needed to prevent premature solids breakthrough. (Solids breakthrough is the appearance of large quantities of solids in the filter effluent.) The choice of polymer does not greatly affect process decisions. If the decision is made to carry the direct filtration alternative forward, the choice of polymer can be made later, after pilot testing.

__Rapid Mixing__

It is generally accepted that primary coagulants should be distributed throughout the water as rapidly and thoroughly as possible. The iron complexes responsible for charge neutralization (the most efficient method of particle destabilization) are short-lived. This destabilization mechanism is effective only if particles are brought into contact with the complexes within a time span less than the complexes' lifetime. On the other hand, rapid mixing time and intensity have limits. Overly intense mixing or mixing for too long can break the fragile, newly established interparticle bonds.

Rapid mixing is often carried out in small, intensively mixed vessels. As a rule of thumb, the product of mixing intensity (G, sec^{-1}) and nominal detention time (t, sec.) is maintained in the range of 1,000 to 2,000. Typically, designers provide G values in the range of 600 to 1,000 sec^{-1}, with contact times of a few seconds. Longer times (2 to 3 minutes) have been used.

Mixing intensity is calculated as follows:

$$G = (P/uV)^{0.5} \tag{2-8}$$

where:

G = average mixing intensity, sec^{-1},
P = power input, ft-lb/sec,
u = absolute viscosity, lb sec/sq ft,
V = tank volume, cu ft

Rapid mixing has also been carried out in other devices:

1. In-line blenders with static mixers or mechanical mixing devices.

2. Hydraulic mixing, in which a hydraulic jump is induced immediately downstream of a Parshall flume used to monitor plant flow. Treatment chemicals are introduced upstream of the jump.

3. Diffusers and injection devices such as grids, venturi mixers, and jet diffusion systems.

4. Jet injection.

The Wahnbach Reservoir Plant appears to add iron directly into a pipeline. The average detention time is about 20 seconds. The Hochdorf plant adds iron to an open-channel venturi meter.

For this analysis, we assume rapid mixing will be conducted in completely mixed tanks operated at a nominal detention time of 2 seconds at peak flow. Turbine mixers equipped with variable-speed drives provide intensities of up to 750 sec^{-1}.

Flocculation

Flocculation provides opportunities for destabilized particles to contact one another and grow in size. Flocculation is clearly needed in sedimentation systems where the objective is to grow large particles that settle readily. Flocculators preceding sedimentation systems are often multi-compartmented vessels in which gentle mixing is provided for 15 to 30 minutes with mixing intensity declining in the direction of flow. Typically, mixing intensities of 90, 50, and 20 sec^{-1} are provided in each of three tanks of nominal detention time of 10 minutes. The Gt product in this configuration is 96,000. Variable-speed drives are often provided to so that operators can adjust stirring to optimize particle size.

There is much less agreement about the need for flocculation preceding filtration systems. Large solids are not preferred since they tend to accumulate at the media-water interface creating densely packed mats that clog the media and result in very short filter runs. Instead, operators prefer to provide relatively small, tough floc which can penetrate and be captured throughout the full bed depth, thus utilizing the bed's total solids storage capacity. Few operators agree on the method needed to produce this ideal floc, possibly because the "ideal" size depends on the characteristics of the filter media used, and conditions required to produce the ideal size are strongly influenced by feedwater quality and the type and dose of polymeric filter aid. Put another way, flocculation requirements are quite site-specific. Some operators recommend taking flow directly from the rapid-mix vessel to the filters with no flocculation. Others, however, prefer some degree of flocculation.

Operators at the Wahnbach Reservoir Plant found that floc were best retained in the filters when the Gt product was in the range of 10,000 to 20,000. If mixing and Gt values were increased further, the floc started to break up and were not retained in the upper coarse media and, in some instances, not retained in the fine media below. On the other hand, longer run lengths were obtained when Gt was in the range of 50,000. Mixing occurs mechanically (with stirrers) and also as the result of the motion created by flowing water. As flow through the plant increased, hydraulically induced mixing increases and the mixer speed can be turned down. At flows exceeding 75 mgd, the mixers can be turned off altogether. The flocculation system in the full-scale plant has two small flocculation basins in series (3 minutes at maximum plant flow rate), with mixer speed adjustable to provide an overall Gt product ranging from 20,000 to 50,000. A cationic polymer (0.1 to 1 mg/l) is added between stages to increase floc strength and solids capture. The water flows to the filters by gravity. Gravity flow avoids the turbulence and floc breakup that would occur if water applied to the filters was pumped.

The Hochdorf flocculator is an equalization tank with a nominal detention time of 25 minutes located immediately upstream of the filters. The flocculator is not equipped with mechanical mixers; flocculation is the result of hydraulically induced mixing alone. A polymeric filter aid (0.2 mg/l) is added in the applied water pipeline to the filters.

For this analysis, we assume a flocculation system based on the Wahnbach Reservoir design will be provided. Each flocculator has two compartments. The nominal detention time in each compartment is 1.5 minutes at peak flow. Horizontal, variable-speed, reel-type paddles provide Gt products in the range of 20,000 to 50,000 sec^{-1}.

Filters

Effective filter design has three goals.

1. Maximize filtration efficiency. The goal is to achieve consistently the desired filtrate quality when treating water that can vary dramatically in flow rate and quality.

2. Obtain high productivity. This goal is accomplished by maximizing the net production rate (NPR). The NPR is the net quantity of filtered water (total water filtered minus water used for backwash) expressed in gallons per day per square foot of filter plan surface.

3. Provide effective filter cleaning. The goal is to clean the filter bed efficiently. The efficiency of this step is measured by the restoration of original headloss and solids storage capacity.

The Wahnbach Reservoir filters have generally achieved these goals.

Filtration Efficiency. As indicated previously, the Wahnbach Reservoir design has achieved very high phosphorus removals. The Wahnbach Reservoir filters use a three-media design. The top media layer consists of 1.2 feet of coarse (3- to 5-mm-diameter) activated carbon. This layer primarily removes bulky sedimentous materials associated with high flows. Solids passing the carbon layer are partially removed in a 4.9-foot-deep middle layer of medium-size anthracite (1.5- to 2.5-mm-diameter). Very fine solids (microalgae, for example) are removed in a 2-foot-deep bottom layer of sand (0.7- to 1.2-mm-diameter).

The performance of the Wahnbach Reservoir units is exceptional with particulate removals in the 99 percent range. The particulate removal performance of the Hochdorf units is not quite so good. The difference in performance might possibly be attributed to the Wahnbach staff's diligent efforts to present the filters with floc that can be readily separated.

Productivity. NPR is an indicator of filter productivity. NPR is calculated as follows:

$$NPR = 24\ [60(Q/A)_f(RL) - (Q/A)_{bw}\ (BWT)]\ /\ (RL + CT) \qquad (2\text{-}9)$$

where:

NPR = net production rate, gpd/sq ft
$(Q/A)_f$ = filtration rate, gpm/sq ft
RL = run length, hours
$(Q/A)_{bw}$ = backwash rate, gpm/sq ft
BWT = backwash time, minutes, and
CT = filter cleaning time, hours.

Inspection of Equation 2-9 shows that NPR is maximized when the total amount of water filtered $(60(Q/A)_f(RL))$ is large relative to the amount of water used for cleaning $((Q/A)_{bw}(BWT))$. Therefore, high filter rates and/or long filter runs are desirable. Short backwashes at low rates are also helpful. Generally, the amount of backwash should be no more than 3 to 6 percent of the gross water filtered. The NPR is a simple but extremely useful design parameter. The amount of filter area needed is obtained simply by dividing the peak flow by the NPR.

Note that if settled backwash water is of very good quality, it may be feasible to discharge it to the effluent canal instead of recycling it via the influent canal for reprocessing. If washwater recycle can be eliminated, then the backwash term in the denominator of Equation 2-9 drops out, increasing NPR and decreasing plant size. This analysis has used the conservative assumption that settled washwater is recycled for reprocessing.

RL is calculated as follows:

$$RL = 2 \times 10^5\ (SSC)\ /\ [(Q/A)_f\ (C)\ (PR)] \qquad (2\text{-}10)$$

where:

SSC = specific solids capture, pounds of solids in the bed at the end of a filter run divided by filter surface area, sq ft
C_i = influent suspended solids concentration, mg/l (including coagulant chemical solids), and
PR = percent solids removed

Assume, for Basin S-5A, that peak filter influent total suspended solids (including chemical precipitates) are 72 mg/l. Using Wahnbach Reservoir filter operating parameters, assume an SSC of 1.44 lb/sq ft, a peak filtration rate of 6 gpm/sq ft, and a solids removal efficiency of 98 percent. Then, when flows and suspended solids concentrations peak simultaneously (a condition likely to occur in the Everglades):

$$RL = 2.0 \times 10^5 (1.44) / ((6)(72)(98) = 6.9 \text{ hours}$$

Assume further that $(Q/A)_{bw}$ = 31 gpm/sq ft, BWT = 6 minutes, and CT = 0.42 hours (25 minutes). NPR at peak conditions is calculated from Equation 2-9:

$$NPR = 24 [60(6)(6.9) - 31(6)] / (6.9 + 0.42) = 7{,}534 \text{ gpd/sq ft}$$

If peak flow for treatment is 835 mgd, then the filter area required = 835 x 10^6/ 7,534 = 111,831 sq ft. At average conditions (Q/A_f = 2.8 gpm/sq ft, filter influent total suspended solids = 32 mg/l), run lengths would be about 33 hours.

Notice the very large difference between SSC for the Wahnbach Reservoir and Hochdorf designs. Using the Hochdorf SSC (0.64 lb/sq ft) and the Hochburg solids removal percentage of 87 percent, with all other parameters the same, RL at peak conditions is calculated to be 3.5 hours, NPR to be 6,548 gpd/sq ft, and filter area to be 127,503 sq ft.

The lower solids storage capacity of the Hochburg design may be due to surface straining. Surface straining occurs when a high percentage of the wastewater solids is captured in the first few inches of the top filter media. The solids form a dense and relatively impermeable mat, which offers high resistance to flow. As a result, head loss builds rapidly, making filter runs short and NPR low.

<u>**Filter Cleaning**</u>. The Wahnbach Reservoir Plant uses air scour and backwash for filter cleaning. To start the cleaning cycle, the water level in the filter boxes is drawn down to a point below the washwater collection troughs but still above the filter bed. This action prevents loss of filter media during the subsequent vigorous cleaning procedures while still maintaining sufficient water in the filter to provide media fluidity. Next, air is injected into the filter underdrains at the rate of approximately 4 cfm/sq ft of filter surface. The roiling action produced dislodges wastewater and chemical solids from the media.

After a short period of air scouring, the air is turned off, and backwash water is injected through the underdrain at a rate of about 31 gpm/sq ft of filter surface area. The backwash water fluidizes and restratifies the filter media in the desired coarse-to-fine configuration while simultaneously flushing the wastewater and chemical solids from the bed and out the washwater collection troughs. The solids-laden spent backwash water is sent to tanks where the solids are settled out. The clarified supernatant is returned to a reservoir located upstream of the filter plant.

Backwash water needed for filter cleaning is about 3 percent of the total filter flow. The backwash water is filtered effluent, which is supplied from an elevated storage tank.

The Hochburg cleaning procedure is similar except that a combined air scour/backwash is used in between the air scour only and backwash only operations.

Recommended Filter Design. The Wahnbach Reservoir design combines high filtration efficiency with high productivity. These characteristics are essential for Everglades treatment systems. Therefore, the recommended design is similar to the Wahnbach Reservoir design.

The Wahnbach Reservoir filter system operates at a maximum instantaneous filter rate of 6 gpm/sq ft. The limiting filter rate for the Hochburg system is much higher, however. Furthermore, other systems have been able to operate effectively (for turbidity removal) at higher rates (Kawamura, 1975; Wagner and Hudson, 1982). It is therefore possible that phosphorus might be effectively removed at higher rates (and lower costs) than in the Wahnbach system. Therefore, we have evaluated a low-rate system (maximum instantaneous filter rate = 6 gpm/sq ft) and a high-rate system (maximum instantaneous filter rate = 11 gpm/sq ft) to cover the range of possible application in the Everglades project. However, filter rates that can actually be used in full-scale systems must be determined by pilot-scale testing with EAA waters.

In addition to maximum instantaneous filtration rates, Table 2-5 also lists average filtration rates for the plants on the days when they are actually in operation (plants are not operated in dry weather, because there is no flow). Average filtering rates in the Basin S-5A filters are quite low (2.8 gpm/sq ft), indicating filter underutilization.

The proposed system utilizes a taller-than-usual filter structure and washwater troughs which are located high above the filter media to allow gravity drainage of spent backwash to the spent backwash basin. This arrangement avoids double pumping of backwash water.

Sludge Treatment and Disposal

The wastewater and chemical solids in the waste washwater are the process residues. These residues (sludges) must be disposed of in a safe and environmentally sound manner.

Sludge Production. Table 2-5 shows estimated maximum and average annual sludge production estimates for Basins S-5A and S-7 direct filtration systems. Sludge treatment and disposal facilities are sized to handle maximum annual sludge production rates. Operating and maintenance (O&M) costs are keyed to average sludge production rates.

Regulations Governing Sludge Treatment and Disposal. USEPA and FDER have no specific requirements for sludges that result from a precipitation process applied to agricultural stormwater runoff. It is conceivable, however, that current or proposed regulations for domestic sludges and/or solid wastes could be used as guidelines for future regulations. This analysis recognizes that such regulations might eventually be applied to direct filtration sludges.

Heavy metal concentration and loading criteria exist for domestic sludges and solid wastes. If these criteria are applied to Everglades systems, and sludge metal or other contaminant concentrations are high, disposal-site life could be severely restricted. The magnitude of such potential restrictions can be determined once direct filtration sludges have been analyzed for contaminant content.

Groundwater protection is another issue. It is possible that the District will be required to demonstrate that groundwater beyond the boundaries of the sludge disposal site will not be contaminated by sludge treatment and disposal practices. Contaminants could include regulated parameters as well as phosphorus.

It is unlikely that direct filtration sludges will be classified as hazardous wastes. They are not listed[1] wastes nor do they exhibit ignitable, corrosive, or reactive characteristics. While there is a remote possibility that they could exhibit the characteristic of toxicity, toxicity can only be determined empirically once the sludges have been generated. Sludge toxicity testing will be conducted if pilot-scale testing is conducted for the direct filtration alternative. The analysis assumes that no special features of hazardous waste systems (for example, basin liners, leachate collection systems, monitoring wells, or permits) will be needed for the treatment and disposal of direct filtration sludges.

Treatment and Disposal Options

Several treatment/disposal combinations have been considered for direct filtration sludges. They include:

1. Thickening alone, followed by spreading of the thickened sludge on farmland. The sludge would serve as a low-grade fertilizer or soil amendment.

2. Thickening alone, followed by disposal of thickened sludge on land dedicated specifically for that purpose.

3. Thickening and mechanical dewatering (by centrifuge, belt filter press or plate-and-frame filer presses pressure filter), followed by spreading of dewatered sludge on farmland.

4. Thickening and mechanical dewatering, followed by disposal of dewatered sludge on dedicated land.

[1] Under the Resource Conservation and Recovery Act, a sludge is hazardous if it is listed in Title 40 of the Code of Federal Regulations, Part 261, Subpart D, or if it is generated by treatment of a listed waste.

5. Thickening and dewatering (by plate-and-frame filter presses pressure filters), followed by disposal of dewatered sludge in a lined landfill equipped with a leachate collection system.

The calculations indicate that Option 2, thickening followed by dedicated land disposal, is the most economical option. Options 1 and 3, which include disposal of sludge on farmland, do not appear promising. The sludges will have little fertilizer value, with almost no nitrogen and very little phosphorus (0.5 percent at most). Furthermore, the sludge's iron content will be high (15 to 30 percent). Further investigation is needed to determine if the high iron content could make the sludge toxic to crops or harmful to grazing animals. Sludge marketing would also be required for agricultural options; it would not be needed for other disposal scenarios. Of the other disposal scenarios, Option 2 costs less than Options 4 and 5, because it does not involve mechanical dewatering. Option 5, while relatively expensive, removes uncertainties associated with site life and groundwater protection. Option 2 is tentatively selected on the basis of cost. Option 5 is the fall-back alternative.

Option 2 involves transfer of waste washwater to an earthen basin. The basin provides flow equalization and a place for the solids to settle and thicken. The clarified supernatant is decanted and drained by gravity to the treatment plant influent channel. The sludge that settles to the bottom of the basin thickens by gravity to a solids concentration of roughly 7 percent. The basin is sized to accumulate 6 months of 7 percent sludge to an average depth of 4 feet. The depth of the clear supernatant overlayer is 11 feet.

During dry weather, the thickened sludge is pumped from the bottom of the basin by a floating dredge and transferred to small sludge holding tanks. Some liquid entrainment is expected to accompany dredging. Therefore, the concentration of the dredged material is expected to be about 5 percent. Tank trucks take the sludge from the holding tanks and distribute it below the surface of the dedicated land disposal site. Sludge dredging and disposal occur during dry weather when sludge-associated water can be removed by evaporation.

The dedicated landfill site should be designed so nearly all of the water in the sludge evaporates during dry weather. Near total evaporation of sludge water minimize its migration into groundwater. Therefore, the site is designed so that net soil evaporation (NSE) dries the sludge. NSE is calculated as follows:

$$NSE = (PE \times K) - R \qquad (2\text{-}11)$$

where:

NSE = net soil evaporation during a specified period, inches,
PE = pan evaporation during the specified period, inches
K = evaporation factor, and
R = rainfall during the specified period, inches

Sludge will dry when the NSE is positive; it will not dry when the NSE is negative. Therefore, sludge is applied only during those periods with positive NSE, i.e., during dry weather.

The permissible sludge loading rate (PSL) is determined by equating the sludge water load and the net cumulative positive NSE. Equation 2-12 is the result of this balance.

$$PSL = 1.1326 \times NSE \times PS/(100-PS) \quad (2\text{-}12)$$

where:

PSL = permissible sludge loading rate, tons dry solids per acre per specified period, and
PS = sludge percent solids.

NSE were calculated in Basin S-5A for each month during the 1977-1988 period of record, using an evaporation factor of 0.6. Corresponding PSL for each month were calculated at the same time, assuming PS = 5 percent. The positive monthly PSL were summed for each year (roughly half of the months had positive PSL and were suitable for sludge spreading) to give annual PSLs. PSLs varied from 26 tons dry solids per acre per year in 1980 to 71 dry tons per acre per year in 1981. In 1982, the year in which sludge production would have been the highest had a treatment plant been operating, PSL was 28.4 dry tons per acre per year. This rate was used to size Basin S-5A dedicated land disposal site. It was also used to size Basin S-7 dedicated land disposal site, even though Basin S-7 PSL was actually slightly higher.

Option 5 is the fallback alternative if the life of the dedicated land disposal site appears to be severely restricted by metals or other contaminants, or if assurance cannot be given that groundwater can be protected. Solids thickening is accomplished in the earthen waste washwater basin described previously. Thickened sludge is pumped by a floating dredge to sludge storage tanks. The thickened sludge is dewatered to about 35 percent solids in filter presses. The dewatered sludge is deposited in an aboveground landfill equipped with liners and leachate and runoff collection systems. The active area of the landfill is 20 acres; its total area, including buffer strips, is 40 acres. It is 15 feet deep and designed to hold 20 years of sludge. Landfill life is not limited by environmental considerations. Runoff and leachate control protect the groundwater. The additional cost of Option 5 does not destroy the economic viability of the direct filtration alternative (see Costs, below).

Land Requirements

Table 2-8 summarizes land requirements for Basin S-5A and Basin S-7 direct filtration options. The dedicated land disposal area consumes by far the greatest portion of the plant site. The filters are very small in comparison, and whether the filters are low-rate filters or high-rate filters has virtually no impact on land requirements. If the sludge dewatering/landfill option (40 acres) is used instead of dedicated land disposal of thickened sludge (336 acres), plant land requirements drop dramatically, from about 424 acres to about 125 acres.

Table 2-8 Land Requirements for Proposed Basin-Scale Direct Filtration Facilities

Item	Land area, acres			
	Basin S-5A filters		Basin S-7 filters	
	Low rate	High rate	Low rate	High rate
Influent pump station	0.2	0.2	0.2	0.2
Chemical addition and storage	0.7	0.7	0.1	0.1
Rapid mix and flocculation	0.1	0.1	0.05	0.05
Sedimentation basins	-	-	-	-
Filters and backwash	4	2.3	1.0	0.6
Sludge thickening basins	13	13	5.5	5.5
Dedicated land disposal	336	336	159	159
Operations building	0.4	0.4	0.4	0.4
STAs	-	-	-	-
Effluent pump station	-	-	-	-
Miscellaneous	70	70	20	20
Sum	424	423	186	185

COSTS

The following text discusses assumptions used in developing cost estimates, and the results of those estimates.

Capital Costs

Table 2-9 summarizes capital costs for the basin-scale direct filtration options. Capital costs for basin-scale alternatives were estimated with BACPAC, Brown and Caldwell's computerized cost estimating and scheduling program. Costs are expressed in December 1992 dollars, for construction projects in South Florida. Appendix B contains a further breakdown of costs by alternative.

Basin-scale capital cost differences are attributed solely to differences between the filters since all other process components cost the same. Table 2-9 shows that the filtration rate can significantly affect capital costs.

We estimated the effect on Basin S-5A capital costs of using sludge dewatering/landfilling instead of dedicated land disposal of thickened sludge. The substitution increased estimated capital costs by about $9.8 million.

Table 2-9 Estimated Capital Costs for Basin-Scale Direct Filtration

Item	Capital costs, million dollars[a]			
	Basin S-5A		Basin S-7	
	High rate	Low rate	High rate	Low rate
Contractor indirects	1.66	1.66	1.00	1.00
Influent channel	0.20	0.20	0.20	0.20
Yard development	0.96	0.96	0.60	0.77
Influent pump station	5.55	5.55	3.59	4.51
Water feed channel	0.87	0.87	0.24	0.24
Rapid mix	0.77	0.77	0.21	0.21
Flocculation	1.66	1.66	0.49	0.47
Filters	29.14	44.44	7.92	12.33
Chemical addition	0.68	0.68	0.30	0.37
Backwash	3.23	3.23	0.72	0.84
Sludge thickening	0.61	0.61	0.39	0.39
Sludge holding	0.35	0.35	0.15	0.15
Land disposal	0.89	0.89	0.31	0.45
Effluent channel	1.66	1.66	1.66	1.66
Yard piping	2.10	2.10	1.05	1.05
Electrical/instrumentation	11.02	11.02	5.77	5.77
Operations building	0.79	0.79	0.56	0.64
Subtotal	62.17	77.47	25.18	31.35
Bond	0.62	0.77	0.25	0.31
Subtotal	62.79	78.24	25.43	31.66
Engineering at 15 percent	9.42	11.74	3.81	4.75
Construction contingency at 20 percent	12.56	15.65	5.09	6.33
Land purchase	1.37	1.38	0.44	0.44
Land contingency	0.76	0.76	0.15	0.15
Total capital cost	86.90	107.77	34.92	43.33

[a] Costs in December 1992 dollars.

O&M Costs

Table 2-10 summarizes O&M costs for the basin-scale direct filtration options. O&M costs are broken down by treatment unit in spreadsheets contained in Appendix C. Appendix C also contains a listing of assumptions used in deriving O&M costs.

Table 2-10 Estimated Annual Operating and Maintenance Costs for Basin-Scale Direct Filtration

Item	O&M cost, million dollars per year[a]			
	Basin S-5A		Basin S-7	
	High rate	Low rate	High rate	Low rate
Labor[b]	0.72	1.06	0.44	0.63
Materials[b]	0.22	0.25	0.14	0.16
Chemicals	0.56	0.56	0.41	0.41
Energy	0.46	0.46	0.28	0.28
Monitoring	0.15	0.15	0.15	0.15
Total	2.12	2.49	1.43	1.64

[a] December 1992 dollars.
[b] Does not include labor and materials for monitoring; these costs are included separately under "monitoring."

High-rate filtration plants have lower O&M costs than low-rate filtration plants because they have fewer filters, hence fewer operators. O&M costs in Basin S-5A and Basin S-7 are roughly in the ratio of average flows treated.

Note that O&M labor is assigned to treatment units only when the units are operating. For example, Basin S-5A filters are assumed to operate only one-third of the time, because historically flows occur only one-third of the time. Therefore, labor costs assigned to the filters are one-third the amount that would be assigned if the filters were operated full time. It is assumed that the District will find other productive work for treatment plant personnel when the treatment plants are not operating.

The effect on Basin S-5A O&M costs of substituting sludge dewatering/landfilling for disposal of thickened solids on dedicated land is estimated to increase O&M costs by about $0.86 million per year.

Present Worth Costs

Present worth costs can be calculated by:

$$PW = CC + f\ (O\&M) \qquad (2\text{-}13)$$

where:

PW = present worth in current dollars
CC = capital cost in current dollars
f = O&M cost factor
O&M = O&M costs in current dollars

The O&M cost factor f is 9.8181, based on a 20-year equipment life and an 8 percent discount rate. The estimated present worth costs for the basin-scale direct filtration options (using dedicated land disposal) are:

1. Basin S-5A

   A. High-rate filters = $110 million.
   B. Low-rate filters = $134 million.

2. Basin S-7

   A. High rate filters = $48 million.
   B. Low-rate filters = $60 million.

Substituting sludge dewatering/landfilling for dedicated land disposal of thickened sludges increases Basin S-5A direct filtration system present worth by about $18.2 million.

Table 2-11 presents the cost of phosphorus removal, expressed in dollars per pound of phosphorus removed and total present worth cost. This cost is obtained by dividing the system's present worth by the weight of phosphorus removed over the project life. The unit cost for Basin S-5A systems are less than the unit costs for Basin S-7 systems.

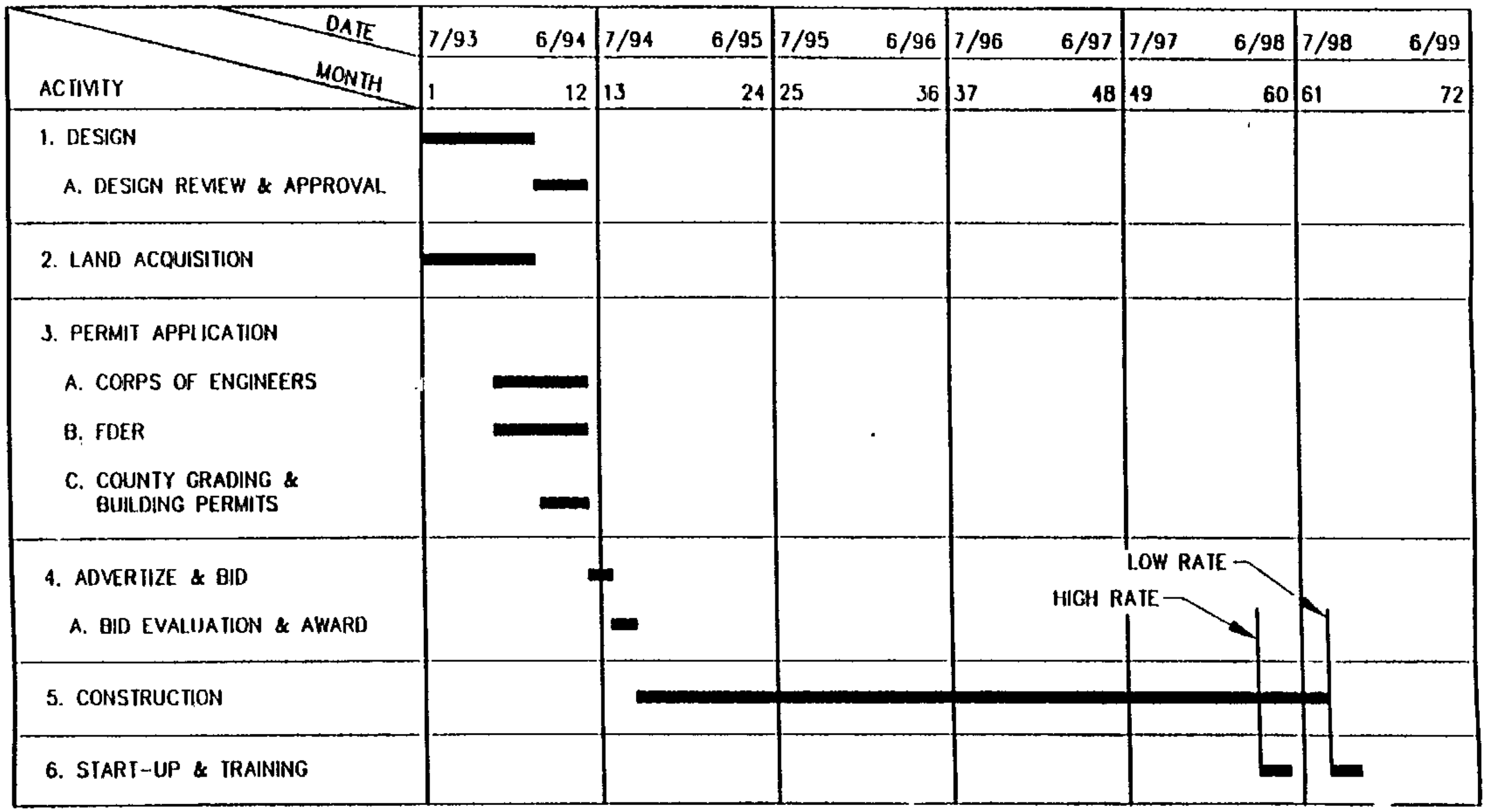
Implementation Schedule

Tentative implementation schedules for direct filtration alternatives at Basins S-5A and S-7 are shown on Figures 2-9 and 2-10, respectively. Activities required for implementation of the projects include design, land acquisition, permit acquisition, advertising and bidding, construction, and start-up and operator training. Direct filtration could be completed and operational in 47 months in Basin S-7. High-rate direct filtration would take 61 months to complete at Basin S-5A, while low-rate filtration would take 68 months. Once in operation, direct filtration would immediately achieve the desired phosphorus removals; there would be no initial operation period required to achieve steady-state conditions as would be required for STAs.

Table 2-11 Present Worth Estimates of Basin-Scale Treatment Alternatives

Item	Cost, millions of December 1992 dollars: Capital	O&M	Present Worth[a]	Dollars per pound of P removed
Basin S-5A				
STA	118.2	3.53	152.8	96[b]
Direct filtration				
High rate				
with dedicated land disposal[c]	88.8	2.12	109.6	68
with mechanical dewatering/landfill	98.6	2.98	127.8	80
Low rate[c]	109.7	2.49	134.1	84
Chemical treatment with wetlands[c]	169.9	3.61	205.3	128
Basin S-7				
STA	62.0	2.02	81.8	146[d]
Direct filtration				
High rate[c]	34.4	1.43	48.4	86
Low rate[c]	44.0	1.64	60.1	107
Chemical treatment[c]	56.8	1.79	74.4	133

[a]Present worth = capital cost + factor (O&M cost)
Factor, based on 20 years equipment life and 8 percent discount rate = 9.8181
[b]1.60 million pounds P removed in Basin S-5A over 20 years.
[c]Costed for disposal of thickened sludge on dedicated land.
[d]0.56 million pounds P removed in Basin S-7 over 20 years.



E:/7138/FIG2-9

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FIGURE 2-9.
IMPLEMENTATION SCHEDULE FOR
DIRECT FILTRATION AT BASIN S-5A

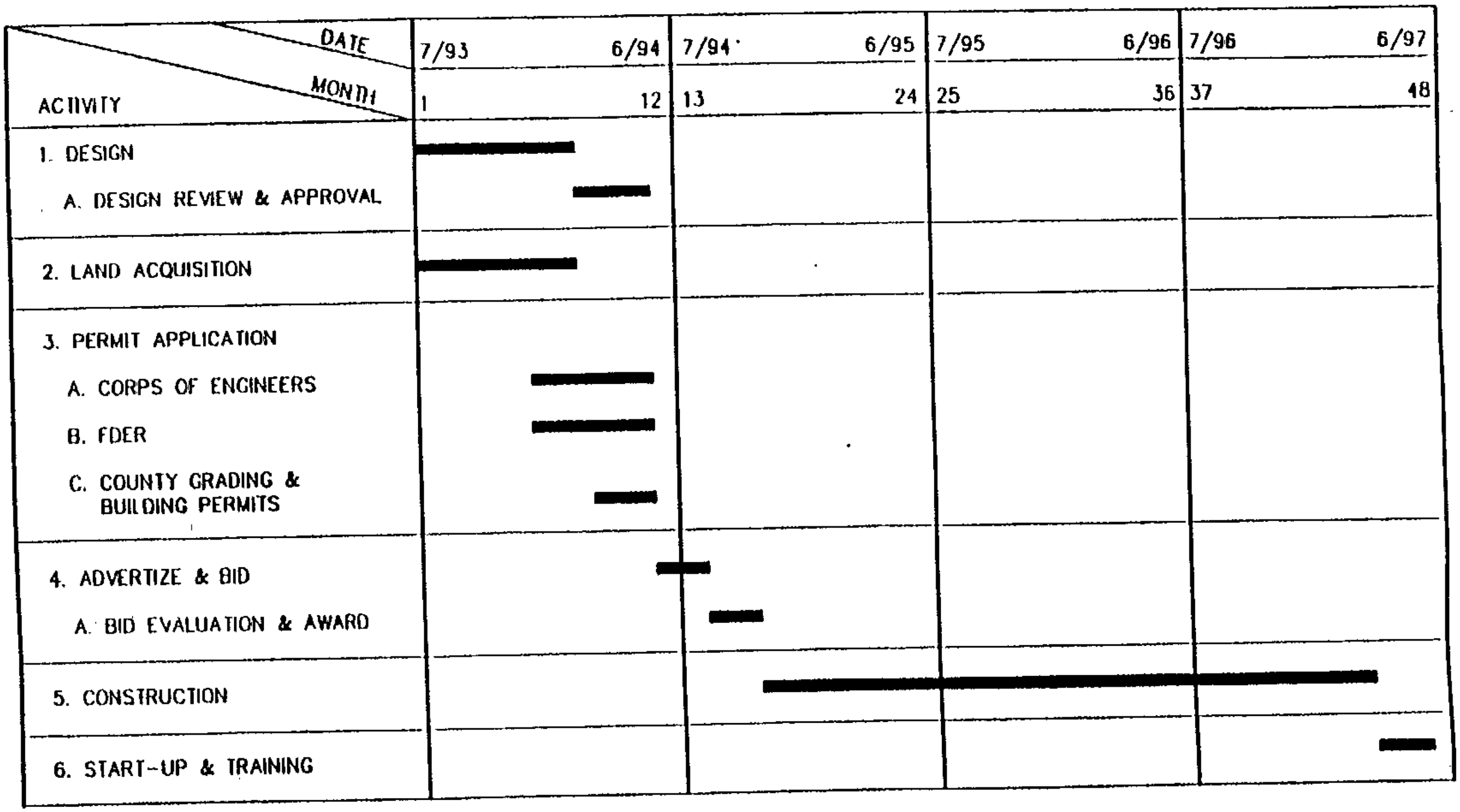

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FIGURE 2-10.
IMPLEMENTATION SCHEDULE FOR
DIRECT FILTRATION AT BASIN S-7

/7138/FIG2-10

It is assumed that a federal Environmental Impact Statement (EIS) will not be required; if it is, completion of the project could be delayed by approximately 6 months if the permitting agencies decide to wait until the EIS process is successfully completed (i.e., the EIS is unchallenged) before issuing their permits. If the EIS is challenged in the courts, the delay would be longer and not possible to estimate at this time.

STA DESIGN BASIS CONSIDERATIONS

STAs have been proposed for treatment of waters emanating from the EAA. STAs are very large constructed wetlands with associated levees; flow control structures; inflow, outflow, and seepage return pumps and piping; and road bridges. The STA for Basin S-5A requires 12,200 acres of land and is estimated to cost $118 million. (Burns & McDonnell, March 31, 1992, Phase 2 capital costs inflated to December 1992 dollars. It is assumed that Phase 1 capital costs are not recoverable.) The STA for Basin S-7 requires 6,220 acres of land and is estimated to cost $62 million (Burns & McDonnell, March 31, 1992). The total estimated costs in Burns & McDonnell's report has been adjusted to reflect current costs to allow direct comparison with the estimated capital costs of the alternative treatment technologies we are evaluating.

The O&M costs of STA operation have also been estimated. The O&M cost for Basin S-5A is estimated to be 3.53 million per year. The O&M cost for Basin S-7 is estimated to be $2.02 million per year. Spreadsheets documenting the O&M costs can be found in Appendix C.

The present worth of the Basin S-5A STA is estimated to be $153 million. The present worth of the Basin S-7 STA is $82 million.

This section presents a review of the design of the STAs as presented by Burns & McDonnell in their report. The purpose of this section is to discuss issues of concern in terms of the adequacy of the STAs to reach the desired treatment levels, as well as some considerations on cost and project implementation.

The original purpose of the STAs was to reduce phosphorus, thus preventing the alteration of the natural species compositions within the Everglades National Park and the WCAs south of the EAA. The historic species composition within the Everglades and surrounding lands consists of species which developed under oligitrophic conditions. The introduction of phosphorus rich waters through the construction of drainage canals and the draining of fertilized nutrient rich farmland has lead to eutrophication and the encroachment of species which thrive in more eutrophic environments. The present goal of the project is to use the STAs to reduce phosphorus levels to 0.05 mg/l prior to discharge to the WCAs. Compliance with the 0.05 mg/l goal is to be measured over a long-term basis such as the 9.75-year period of record used to develop the design criteria for the STAs. The cost of constructing and maintaining the STAs necessitates that there be a high degree of confidence in the ability of the system to reduce species alteration, and that the systems begin to work in a reasonable amount of time.

The following presents possible concerns which should be addressed prior to initiation of detailed design of the STAs. The possible impacts of these concerns in terms of project cost and success are addressed with each concern where applicable.

Major Concerns

Given below is a list of the major concerns of the STA design including examples. Following the outline is a detailed examination of each concern.

1. Design Concept Issues

   - Transferability of observations of phosphorus removal in WCA 2A to the STAs.

     - Soils (oxidation and subsequent concentration of phosphorus, rehydration, soil pore water phosphorus concentration, pH, and other chemical constituents).

     - Speciation of phosphorus (particulate versus soluble).

     - Land uses (farming and fertilizer application).

   - Phosphorus removal mechanisms (chemical binding; algal deposition; soil adsorption; and vegetative uptake, growth rates, and decomposition or accumulation).

   - Model validation.

   - Atmospheric phosphorus deposition approaches the objective of 0.05 mg/l phosphorus concentration.

   - Optimized design and operation (STAs are proposed on a greater scale than any prior natural wetland).

   - Lack of site-specific information.

   - Conflicts with predominant literature findings for an unmanaged wetland system to consistently achieve a phosphorus concentration in this range (systems in operation show variability in performance and inconsistency when phosphorus concentrations are this low).

   - Wetland treatment systems designed and constructed to date have not been designed based solely on soil accumulation (hydraulic and nutrient loading, vegetative uptake and growth rates, and soil adsorption have been considered).

2. Soil Related Issues

- Soil/water column interaction and its effect upon phosphorus uptake rates.
- Role of calcium in phosphorus removal.
- Depth of soil.

3. Performance/Reliability Issues

- Ability to achieve concentration goals within desired time frame (initial flush of phosphorus from accumulation in soils and soil pore water, length of time for vegetation to grow sufficiently, point at which additional planting is not cost-effective, and property acquisition).

- Life of the system (how long before steady state is achieved, not enough net productivity and vegetative matter accumulation to achieve the target phosphorus concentration; and, how long before the finite capacity of soils for adsorption is expended).

- Management considerations (maintenance harvesting while maintaining adequate process controls, zonation of application, channelization and short circuiting, and undesirable vegetation).

- Relatively low control over the mechanisms responsible for phosphorus reduction (compared, for example, to treatment by chemical addition).

4. Engineering Issues

- Wave action, resuspension of phosphorus in sediments and length of time for vegetation to create quiescent conditions.

- Development of an accurate water balance, considering actual vegetation, and water losses.

- Flow equalization (the ability of the system to function during all hydrologic regimes without sacrifice of performance, overgrowth of algae, or loss of plant viability).

5. Biological and Other Issues

- Inclusion of open water in the system design (the basis for this inclusion is not clear).

- Property acquisition.

- Role of algal decomposition.

Design Concept Issues

The following paragraphs briefly describe concerns related to the current STA design concept.

Transferability of Observations of Phosphorus Removal in WCA 2A to the STAs. Wetland treatment systems have proven successful in full-scale systems in removing phosphorus from the water column. Technical issues have been presented regarding the design basis used for the STAs. Central to these concerns is the lack of directly transferable evidence that the proposed STAs can consistently produce an effluent with a phosphorus concentration of 0.05 mg/l.

Attempts were made in the STA design to use data from wetland systems that are geographically proximate to the STAs or that have some similarity in vegetation, hydraulics, prior land uses, or phosphorus concentrations. The fact remains, however, that the confidence level for the STAs would be enhanced by the availability of more directly usable data, such as will be provided by the ENR Project. Stated another way, exception is taken not so much with the particulars of the STA design approach, but by the relative shortage of transferable data on which to base any design. Since the settlement agreement dates do not allow time to develop the required transferable data, an analysis is made herein of the STA design as presented by Burns & McDonnell.

Knowing the types of phosphorus that the STA is expected to treat is a minimum requirement to design it with reliability; if the phosphorus is predominantly particulate, the system should be designed to enhance opportunities for sedimentation, filtration, and plant contact. If more of the phosphorus is soluble, the system should be designed to facilitate adsorption, plant uptake, and chemical precipitation. Also, the effects of the proposed farm Best Management Practices (BMPs) on phosphorus speciation should be estimated. The BMPs would be expected to be more effective in removing particulate phosphorus, leaving a greater proportion of the phosphorus reaching the STAs as soluble, which is not as readily removed and is more sensitive to variations in conditions in the STAs.

Although considerable data are available on the performance of wetlands in reducing phosphorus concentration, these existing systems and the STA design are too dissimilar to allow comparison, as was pointed out in Nolte. In particular, most wetland treatment systems are operating with constant flows from domestic wastewater treatment plants with comparatively little variation in flow rate and in annual phosphorus concentration as compared with the pulse loading that the STAs are required to handle.

The transferability issue is also addressed somewhat in the section on Soil/Water Column Interaction where it stated that the 8 m/yr is for an undisturbed cattail/sawgrass wetland system while the STAs are to be built upon land which has been historically farmed. Therefore, the design is based on the STAs reaching a state which is similar to the undisturbed WCA 2A. An estimation of the time for this to occur seems to be lacking, and it will directly influence the viability of the project and the time frame to reach the desired goals.

The time for each STA to reach the desired state will be highly dependent upon historical land use, i.e., degree of fertilization, flooding and drying frequency, amount of time left unfarmed, etc. It will also be dependant upon the degree of planting which will occur and the expenditure on care should be planted along with the herbaceous species. Woody vegetation has been shown to provide both greater capacity and longer term storage for phosphorus than herbaceous vegetation, in part because woody species include more permanent tissue and structures, which are not as quickly available for decomposition and recycling of phosphorus.

The majority of freshwater wetland systems in operation in Florida are operating with a maximum design depth of 4.5 feet and a target average depth of 2 feet, and the use of these parameters appears to be appropriate.

Model Validation. Prior to developing a model from the WCA 2A system, additional data are needed to verify that the settling rate developed from the one transect used is valid for that system. It is important that the model be verified for the system from which the initial data were taken before using that data to predict the performance of another system. If the model does not hold true for the system on which it is based, then that model cannot be applied to another system. The second system will have variations from the original system which will not be accounted for in the model. To have the greatest possible confidence in the ability of the model to predict what will happen in the second system, the model should be as accurate as possible for predicting performance of the first system. One transect, especially given the size (and thus probable variation within the original system), is not sufficient to even describe the original system.

The approach taken in the STA design is basically a "black box" approach. Measurements were taken of what went into the box and what came out, and a simplistic, linear relationship was assumed between the two. To best replicate or even improve on our knowledge of the physical, chemical, and biological processes that took place inside that black box, those processes must be defined and then a determination made of their relative importance. Acreage requirements were calculated for the STAs from the black box without addressing whether length of travel or detention time, if either, was dominant in governing the apparent settling rate. The differences in hydroperiod management between the STAs and WCA 2A must be factored in. WCA 2A experienced dry periods, while the STAs as designed will never be dry. Initial hydroperiod design for the STAs must take into consideration the prevention of slug releases of phosphorus from the newly hydrated organic soils.

The Richardson data shows a settling rate of only 4.6 m/yr for three additional transects, although the data were not flow-weighted and thus not directly comparable to the derived 8 m/yr. Because this difference is sufficiently large, further investigation is warranted.

In designing an STA, the variables that are not equivalent between the STAs and WCA 2A must be taken into account. WCA 2A has long been a wetland, while the STAs have long been in agricultural production and management. Agricultural production includes soil turning, application of fertilizers and pesticides, and soil oxidation from exposure to the atmosphere. Each of these practices can be expected to affect soil phosphorus storage in terms of mass storage and phosphorus form.

and maintenance of planted stock. In the Reddy and Graetz study, soil cores were tested for flushing of soluble phosphorus due to flooding of the soils. Samples from two fields were considered, one from a field which had been flooded for 10 months and one which had been left dry. The dry field showed an initial leaching of 860 mg/m^2 while the previously wet field showed an initial leaching of 169 mg/m^2 phosphorus. This difference indicates that the flushing of oxidized phosphorus from the treatment areas upon flooding will vary significantly in magnitude and directly affect the initial functioning of the system.

Another question is the amount of data used in the determination of the 8 m/yr settling rate. Basically one set of data was used in determining this rate, although it was evaluated using various methods. The limited data brings into question the applicability of this rate to a large variety of land areas with differing historical land uses, soil types, and soil chemistry.

The question of transferability is not so much one of whether a state will be reached which is similar to the WCA 2A, but the amount of time it will take to reach this state, and the amount of cost and maintenance required to achieve it within the desired time frame.

Phosphorus Removal Mechanisms. Physical, chemical, and biological processes are at work in wetland systems which together determine the compartmentalization and net removal of phosphorus. The STA design uses a single parameter to simultaneously represent all mechanisms influencing the fate of phosphorus. This methodology is in effect a "black box" approach to wetland system design; making the assumption that all mechanisms will exert their effects in the same proportion and with the same efficiency provides only a low confidence level in the reliability of the design to achieve its objectives. Variation in a single environmental factor, such as pH, could have a significant impact on the mechanisms such as phosphorus precipitation with metals. The pH variation could, in turn, allow more phosphorus to become available to the vegetation and possibly increase either biomass production or phosphorus tissue concentration. The result is that, without understanding the site-specific mechanisms at work, the all-encompassing rate constant provides only an order of magnitude projection of the net phosphorus removal rate. This variability is evidenced by reviewing the findings from the many wetland treatment systems that are in place throughout North America. In the absence of harvesting, precipitation, plant uptake, sedimentation, and adsorption play varying degrees of importance to the success of wetland systems due to variations in conditions. These variable conditions include hydraulic retention time, dominant vegetation, pH, soil chemistry and texture, flow rates, water depth, nutrient ratios, climate (temperature, rainfall, freeze events, solar intensity), length of time since establishment, and effectiveness of construction (adequate hydraulic controls and maximization of sheet flow). The use of a single rate constant does not attempt to identify or quantify the primary mechanisms specific to a given site or design objective.

The STAs are envisioned to be vegetated primarily by cattail. It is recommended that a variety of vegetation indigenous to the area be planted or mulched and that any volunteer plants be allowed to remain, i.e., whatever is able to grow competitively is thereby well-suited for the site-specific conditions and should grow as well as the cattail (and take up phosphorus to produce new tissue). Although they can spread rapidly and are capable of storing phosphorus in their below ground structures, cattail produce a rather flocculent detrital material that is undesirable. Plants that produce a more sturdy, fibrous litter are preferable. Also, woody vegetation (shrubs and trees)

Soil Related Issues

Soil history, composition, and depth can have major impacts on phosphorus removal. These impacts are discussed in the following paragraphs.

Soil Water Column Interaction and Its Effect Upon Phosphorus Uptake Rates. The flux of phosphorus between the soil and the water column is a highly variable process in both time and space. Depending upon the history of the soils and water column and the present chemistry, the soils can either be a source or a sink for nutrients in the water column.

The primary mechanism for phosphorus removal in the Burns & McDonnell design is peat accumulation due to fallout of decaying plants. Cesium 137 dating of soil sample cores and other methods indicated an average phosphorus accumulation coefficient of 8 m/yr for a transect along WCA 2A. This rate is a long-term net accumulation within a natural cattail/sawgrass wetland system.

The soils to be considered for the STAs are presently agricultural soils which have been historically fertilized and farmed. Tests were performed on soils within the Knight's Farm land, a proposed area for placement of an STA (Reddy and Graetz, 1991). A portion of the study was to determine the phosphate sorption characteristics of the organic soils found within the STAs. The results of the study indicate that "the batch isotherm data presented . . . identify low phosphorus retention capacity of the Everglades Nutrient Removal Project (ENRP) soils in the present state, thus raising concern over the functioning of these soils for phosphorus removal."

Another portion of the study was to determine phosphorus flux rates from the soils to the water column. The calculation of the flux rate was based on two experiments. One measured the vertical gradient of dissolved phosphorus within the bottom sediments and the bottom boundary layer of the water column using porewater equilibrators. The flux rate between the soil and the overlying water column was calculated using Fick's Law of diffusion, which states:

$$F = -nRD\frac{dc}{dz}$$

where:

F = flux
R = resistivity factor
D = diffusion coefficient
n = porosity
dc/dz = concentration gradient of the porewater phosphorus.

The second method was to take soil cores from the field and flood them with water showing phosphorus concentrations equivalent to field conditions. The flux rates were then calculated based upon the changes in water column phosphorus levels. The results showed a wide range in flux values from -1.05 to 13.3 mg/m^2/day for the long-term (30-day) flux rates. The important factor here is that the results show almost exclusively a net flux of phosphorus from the soil to the water column.

In evaluating the results presented above in terms of the design of the STAs, it is important to note that these experiments present only two portions of the phosphorus uptake mechanisms, soil adsorption/desorption and flux of soluble phosphorus across the soil-water interface. The 8 m/yr coefficient is an indication of the net uptake of total phosphorus in a natural wetland and encompasses many more processes such as plant uptake, settling, etc. The physico-chemical nature of the soils will change as the system goes from farmed land into a natural wetland system as seen in WCA 2A, but the question of the time involved to reach this situation. The initial leaching of soils with high soluble phosphorus content will provide an initial pulse of available phosphorus to the areas, and the time required for this leaching to reach a state of equilibrium must be considered in the design.

The second issue raised is the partitioning of phosphorus within the system. Examining the short-term goal of reducing the phosphorus to 0.05 mg/l in the STA effluent versus the long-term goal of returning the Everglades to a more natural species composition requires a knowledge of the forms of phosphorus within the STA influent and effluent. Generally, the soluble phosphorus is that which is available for plant uptake and growth. The flux rates presented above are for soluble phosphorus flux from the soils to the water column. This is material which is available for plant uptake and growth. It is possible to have a reduction in total phosphorus while seeing an increase in the levels of dissolved or available phosphorus (Gehrels and Mulamoottil, 1989). The success of the project will be directly related to reduction of the available levels of phosphorus to the Everglades.

<u>Role of Calcium and Magnesium in Phosphorus Removal</u>. A study of the uptake rates within soil cores taken within WCA 2A indicated a strong correlation between calcium (Ca) and phosphorus (Reddy, DeLaune, Debusk and Koch, 1992). The results "strongly support the hypothesis that Ca loaded to the system readily precipitates the phosphorus in the water column which is then deposited on the soil surface." High pH in the water column (Koch and Reddy, 1992) associated with high periphyton activity and high Ca levels are ideal conditions for phosphorus coprecipitation with calcite (Otsuki and Wetzel, 1972). The report also states "Data on soil phosphorus fractionation (Koch and Reddy, 1992) indicate that Ca and magnesium (Mg) are the dominant factors regulating inorganic phosphorus dynamics in this system." The role of calcium precipitation as a driving mechanism in the uptake of phosphorus in these wetlands is an important one. The question of whether that mechanism will transfer to the STA sites needs to be answered.

Results of studies within the Knight's Farm land indicate that the present soil chemistry does not support precipitation of calcium as a major factor in phosphorus uptake mechanisms and may be the reason for the low assimilation capabilities of those soils. In fractionation experiments on soil cores, the calcium-bound phosphorus was found to be only 3 percent of the total phosphorus within the soil (Reddy and Graetz, 1991). The reason for this low percentage of calcium-bound phosphorus is attributed to the low pH values measured within the soil cores. The soils show high concentrations of calcium and magnesium, but precipitation of phosphorus with calcium requires high pH levels for reaction.

As with other aspects of the physico-chemical properties of the soils, the pH levels and the resultant precipitation of phosphorus with calcium may increase as the sites are flooded and there is increased periphyton activity. Once again, the question of time to reach this situation has not been addressed.

Soil Depth. Although it is not a common consideration in wetland treatment system design, soil depth must not be overlooked in the design of the STAs. In portions of the EAA which have been drained for a long time and where agriculture has been practiced, the depth of soil remaining over the limerock bedrock may be limiting. The soil must be of sufficient depth to support the vegetation. There is one advantage to close proximity of the limerock: calcium is available for precipitating phosphorus.

Performance Issues

There are major concerns about how well the STAs will work, and how soon and how long they will work. These concerns are discussed below.

Performance/Reliability. There is some question as to whether performance can be guaranteed year-round. Peak flow rates and peak phosphorus concentrations are seen together during rainy weather in the summer months. This combination of changing flow rates and phosphorus concentrations exerts a significant level. of variation on loading rates ranging from the low flow, low concentration winter months to the high flow, high concentration summer months.

The ability of the STAs to be capable of providing acceptable levels of treatment in a timely fashion is restricted by the following:

1. Start-up of the system must be delayed until the vegetation is of sufficient height that some parts of the shoots are always exposed to the atmosphere so they have access to oxygen. This means that water depths must remain below the average design depth of 2 feet until the vegetation is at least 2 feet in height. There may be a delay in achieving a steady-state periphyton community, which is an integral ecosystem component for the assimilation of soluble phosphorus, and for raising the pH to enhance phosphorus precipitation. Although decaying periphyton release essentially all of their phosphorus, they slow the movement of the phosphorus through the system, providing a greater residence time to facilitate other mechanisms such as adsorption. The emergent vegetation will provide a several-fold increase in the surface area available for periphyton growth.

2. Even after start-up, there may be a period of net export of phosphorus from the system due to transfer of phosphorus from the soils. Reddy has cautioned that for several months (up to 1 year) the STA may experience a net flux of phosphorus from the soil. One system in Florida showed a net export of phosphorus for 9 consecutive years. The question must be addressed as to what is an acceptable length of time to allow the system to have a net phosphorus export, and at what net mass discharge, and at what point in time would it be no longer acceptable to continue to risk the unknown continued duration of that net export. The phosphorus concentration of the effluent could exceed that of the influent during this period.

Life of the System. Two aspects of the life of the treatment systems are not addressed. The first has been mentioned in the previous sections: how long will it take before the system is working at the anticipated 8 m/yr removal rate? Secondly, how long will the system continue to perform? Once steady state has been achieved, net productivity may not be adequate to consistently ensure the required level of phosphorus reduction.

By defining the mechanism for phosphorus removal as the accumulation of material due to the buildup of peat, the life of the system should only be regulated based upon the accumulation rate of bottom material and the volume of settled material that the basin can hold. The accumulation rate of material in the STAs should be calculated and the life of each system roughly estimated upon the overflow structure elevations and the desired water levels to be maintained.

Engineering Issues

Wave Action, Resuspension of Phosphorus in Sediments. The proposed areal extent of the STAs requires the investigation of some concerns not normally considered in the design of overland treatment systems. With the STAs having open water lengths of as much as 3,000 to 4,000 feet, it is necessary to determine the effects of wind-driven waves, resuspension of bottom material, and wind-driven currents in the design and construction of the systems. The proposed design does not address these issues and their associated costs.

Generally, wetlands have a high density of plant material which pierce the surface of the water and act as damping mechanisms for wind-generated waves. Once the STAs reach a point of equilibrium with a dense growth pattern, the problem of wind-generated waves will be eliminated. The design problem comes in during the period when the vegetative community is being established and only sparse planting has occurred.

The proposed maximum design depth is set at 4.5 feet. High flow conditions will occur primarily under storm conditions with resulting high winds occurring simultaneously. Wind-generated waves will resuspend bottom material if the bottom generated currents exceed the critical shear stress of the soils. The shear stress is calculated as,

$$T_b = p\ C_d\ u|u|$$

where:

T_b = shear stress
p = density of the water
C_d = drag coefficient
u = bottom current magnitude.

Generally, cattails produce a very fine and flocculent sediment which has a low critical shear stress and is resuspended easily. In studies on resuspension of bottom material in shallow open water areas such as Lake Okeechobee (Sheng, 1989), it was determined that wave orbital velocities are the primary mechanism for resuspension of flocculent bottom material. Settling of particulate material and detrital material is the primary mechanism for removal of phosphorus within the treatment areas; therefore, it is necessary that the wind- and wave-driven mixing be reduced to near zero within the treatment areas.

Studies show that phosphorus uptake characteristics of soils within the ENRP study area are highly dependent upon the level of oxidation of detrital material (Reddy and Graetz, 1991). Aerobic conditions within the soils promote oxidation and release soluble phosphorus which can saturate the uptake sites and prevent adsorption of incoming phosphorus. Reducing the level of turbulent mixing will, therefore, promote anaerobic conditions and improve the uptake rates of the soils.

Another concern is the damage to plants as they are establishing themselves due to turbulent wave action as well as damage to berms and levees due to wave impacts.

These concerns dictate that STA design include an evaluation of allowable wave heights within the basin for some predetermined design storm. Evaluation of wave heights from wind speeds and fetch lengths can be determined using established equations such as those developed by the Army Corps of Engineers. Once allowable fetch lengths are established, temporary or permanent wave-break structures should be laid out within the basins, and the associated costs of installation and maintenance estimated. The structures need only be maintained long enough to allow the vegetation to take hold and damp the wave action.

The polishing cells defined in the Burns & McDonnell design are open water basins which use algal communities to remove the remaining phosphorus prior to distribution into the WCAs. The nature of these basins will be such that a very fine flocculent layer will be deposited at the bottom which will be easily resuspended under storm conditions. This water is released directly into the WCAs. More permanent damping structures must be included in the design to maintain some control on the vertical mixing processes and allow the deposition of the algal material. The design requires 2415, 1452, 3101, 2680 acres of polishing cells in STA-1, STA-2, STA-3, and STA-4, respectively. The size of these systems may make it difficult to reduce mixing.

<u>Development of an Accurate Water Balance</u>. The STAs must be able to convey the peak capacity of the influent pump stations while maintaining a 4.5-foot maximum depth within the system. The size of the systems and the relative variability of the vegetative cover makes determination of the flow characteristics using simple formulas inadequate. In addition, the soils found in the WCA 2A areas on which the design is based are permeable, and the length of the system means that some losses of the water will occur as the water flows over the wetland.

<u>Flow Equalization/Hydrology</u>. The flow of water into the STAs will be highly variable and dependent upon episodic storm events. The ability of the system to function depends upon maintaining a flow of water (or at least standing water) within the treatment areas. Drying out of the sites will result in oxidation of the bottom material and cause a pulse of soluble bio-available phosphorus to be released. The rate of 8 m/yr is an average over many years and does not indicate possible variations due to drought or flooding.

Many plant species which may be a part of the system may be sensitive to large variations in the water levels, and during drought periods much of the standing crop may die out. The time for reestablishment of the standing crop may be such that the system fails for an undesirable period of time.

Management practices and the associated costs need to be developed and included in the design of the systems in preparation for drought events. Options include applying agricultural lime on the fields to reduce the initial pulse of phosphorus upon flooding of the soils, pumping outside water into the STAs to maintain water levels during drought periods, and reestablishing the standing crop through maintenance and planting. These options must be considered and included within the cost estimates for design of the STAs.

The largest wetland treatment system in the United States, a 1,230-acre wetland in Lakeland, Florida, has experienced problems with channelization and resultant short-circuiting. Care must be taken to avoid excessive flow velocities that contribute to this problem. The inclusion of collection and redistribution trenches within the STA and along the discharge levee are included in the STA design; we concur with this approach. The redistribution of flow will help prevent hydraulic imbalance, channelization, and the increased velocities that could resuspend the floc.

<u>Biological and Other Issues</u>

<u>Inclusion of Open Water</u>. The basis for creating bermed cells in the STAs and leaving a polishing cell void of rooted emergent plants is not clear. We recommend that essentially all the effective area of the STAs be vegetated with macrophytes, rather than being left open for algal growth. Although algae do consume phosphorus, decaying algal cells release phosphorus back to the water column more readily than do macrophytes.

<u>Property Acquisition</u>. An important factor in the STA design is the ability of the system to reach the desired treatment levels within a predetermined time period. The acquisition of land for use in this purpose will be an extensive task. The raising of capital, the acquisition of the land, and obtaining of all necessary permits, among many other considerations, needs to be addressed as its own separate management task.

<u>Role of Algal Decomposition on the Uptake of Phosphorus</u>. The Burns & McDonnell design for the STAs includes two parallel flowway cells whose design is based upon the 8 m/yr rate of soil accumulation. Following the flowway cells, an open water polishing cell reduces the phosphorus concentrations to the desired output levels through algal uptake and decomposition. All of the experimental data used in support of the STA design is based upon uptake of phosphorus through soil accumulation within a cattail/sawgrass marsh. No data is presented to support the design of algal-based open water treatment areas.

CHEMICAL TREATMENT WITH WETLANDS AND CHEMICAL TREATMENT

The STAs currently proposed in the District's SWIM Plan are designed to be operated as unmanaged wetlands without any form of pretreatment to enhance performance. The chemical treatment with wetlands technology is intended to enhance wetlands performance by providing chemical pretreatment of a portion of the basin flow. It is uncertain how well the STAs will work. Chemical pretreatment with sedimentation reduces phosphorus loads on the STAs and thus improves system performance and reliability. This concept is proposed for Basin S-5A. The chemical treatment system is designed to reduce the phosphorus concentration from 0.187 to 0.10 mg/l. The follow-on STA is designed to reduce phosphorus from 0.10 mg/l to the overall treatment goal of 0.05 mg/l. Chemical treatment alone (without a follow-on wetland) appears to be sufficient to achieve the 0.05 mg/l phosphorus goal in Basin S-7.

Process Description

For the Everglades Protection Project, chemical treatment and direct filtration are similar in many ways. The main differences are that chemical treatment uses greater chemical doses and substitutes settling basins for filters. In this project, chemical treatment consists of influent pumping, chemical addition, rapid mixing, flocculation, and solids separation by means of settling in large, low-cost earthen basins. The settled solids remain in the basins for periods up to 6 months, thickening to solids concentrations of about 7 percent. The thickened sludge is removed from the bottom of the basins by a floating dredge and pumped to small holding tanks. Tank trucks take the sludge from the holding tanks and distribute it below the surface of a dedicated land disposal site using specially designed sludge injection plows. Sludge dredging and disposal occurs only during dry months when the water in the sludge can be removed by evaporation. Mechanical dewatering/landfilling is an alternative to disposal of thickened sludge on dedicated land.

Figure 2-11 is the process flowsheet, and Figures 2-12 and 2-13 are the site layouts for Basin S-5A and S-7, respectively. Figure 2-14 is a conceptual longitudinal cross section of a chemical treatment plant showing the approximate elevations for treatment units. Table 2-12 provides the basis of design. The text that follows discusses design rationale and procedures. As indicated previously, chemical treatment and direct filtration have many common elements, and much of the discussion that follows consists of references to the direct filtration section. Detailed discussions are provided for treatment elements which are unique to chemical treatment.

Chemistry

The chemical principles discussed under direct filtration apply to chemical treatment as well. Iron salts, alum, and lime are the candidate primary coagulants in chemical treatment, as they were in direct filtration. Ferric chloride and alum are again the apparent best treatment chemicals because of low cost and low sludge production. Chemicals for pH adjustment and polymers are the same as used in direct filtration. The current calculations are based on the use of ferric chloride, but alum may prove to be equally effective.

The primary chemical difference between chemical treatment and direct filtration is in the amount of primary coagulant that must be used. Larger chemical doses are needed to produce floc that settle well than are needed to produce floc that filter well. The analysis has assumed average and maximum iron doses of 10 and 15 mg/l, respectively, are required for chemical treatment in contrast to 5.7 and 10 mg/l iron doses for direct filtration. It is assumed that the iron dose is set by destabilization requirements as opposed to phosphorus precipitation requirements. Chemical sludge production is proportional to the chemical dose; thus, overall sludge production is higher for

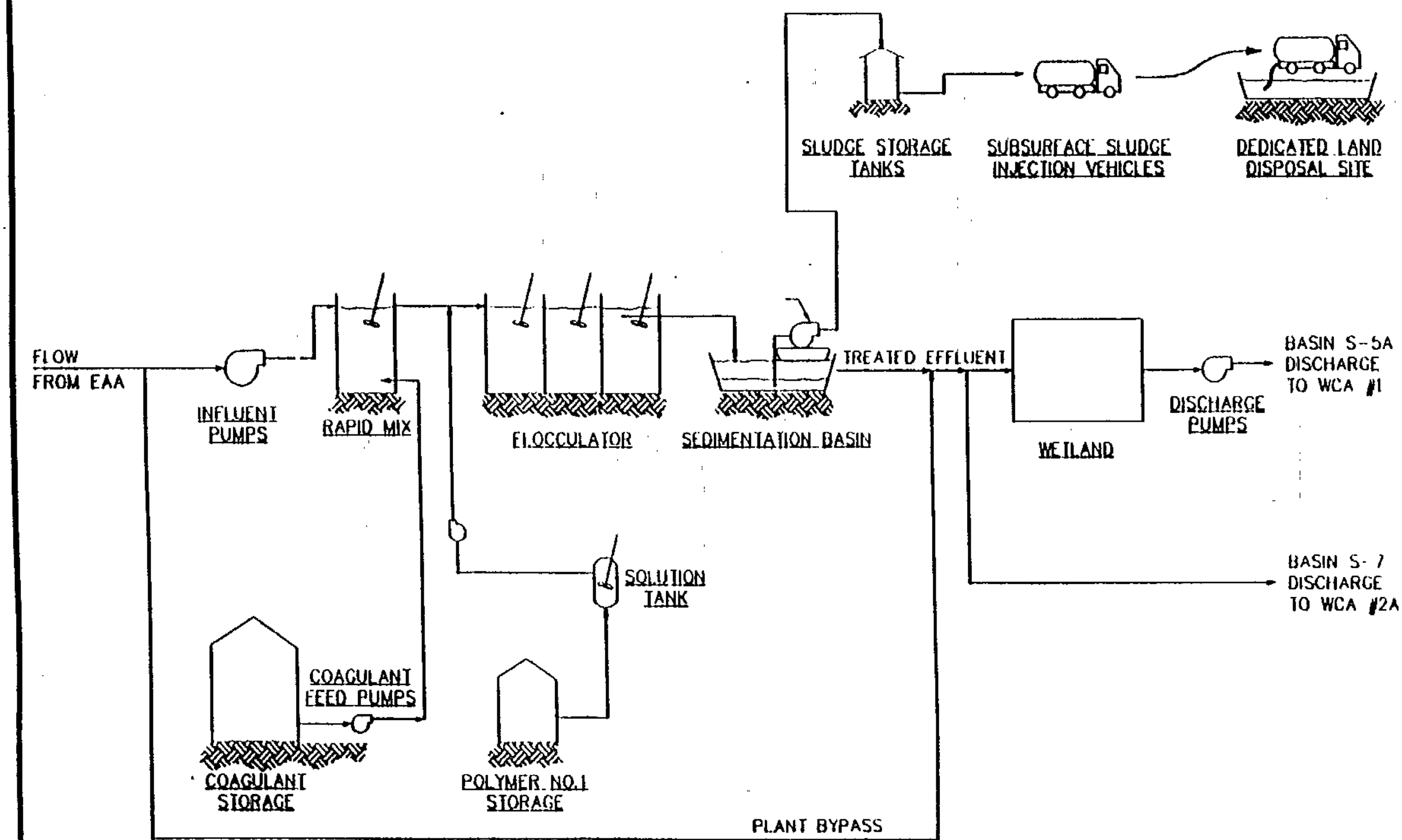

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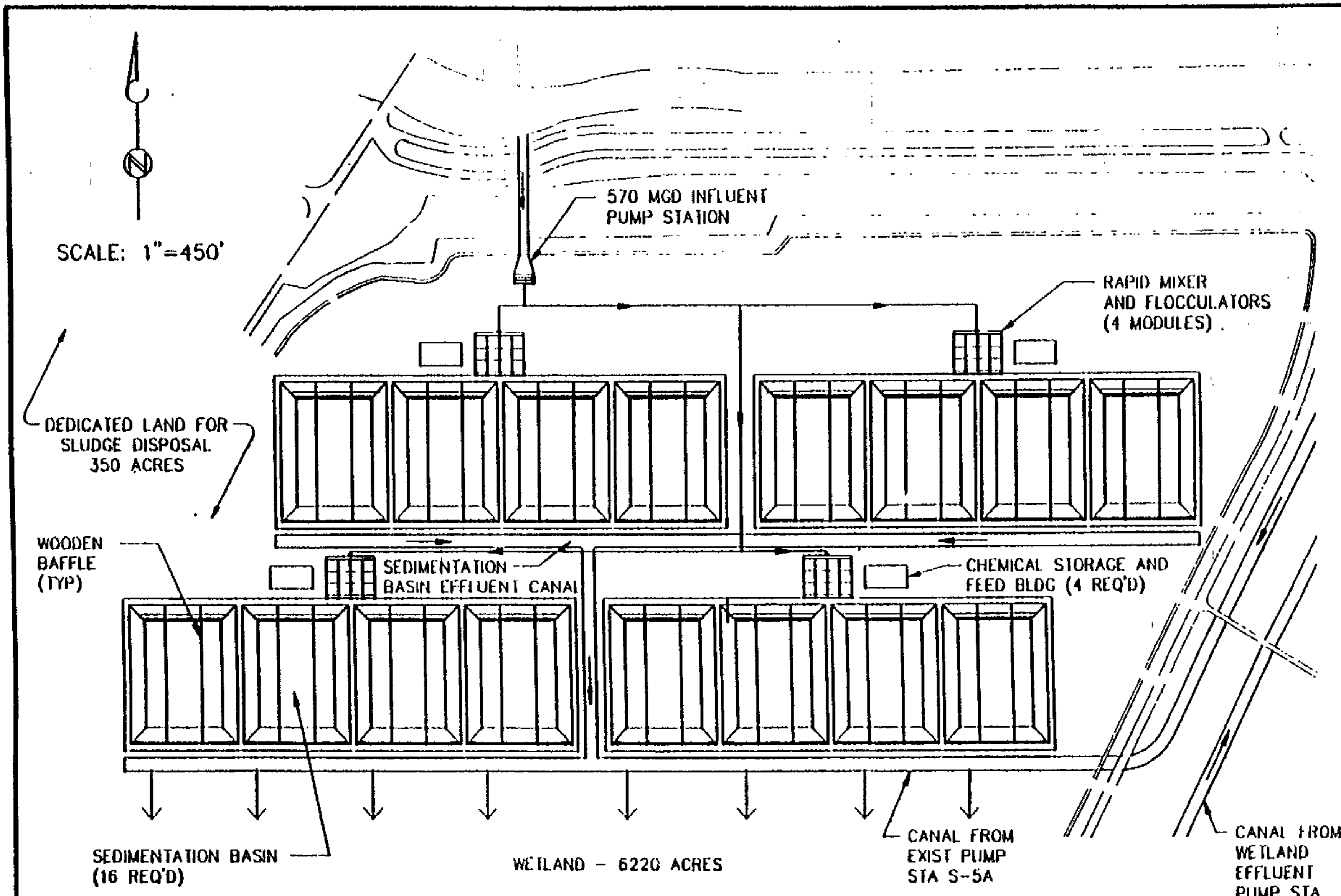
FIGURE 2-11.
CHEMICAL TREATMENT WITH
WETLAND FLOWSHEET



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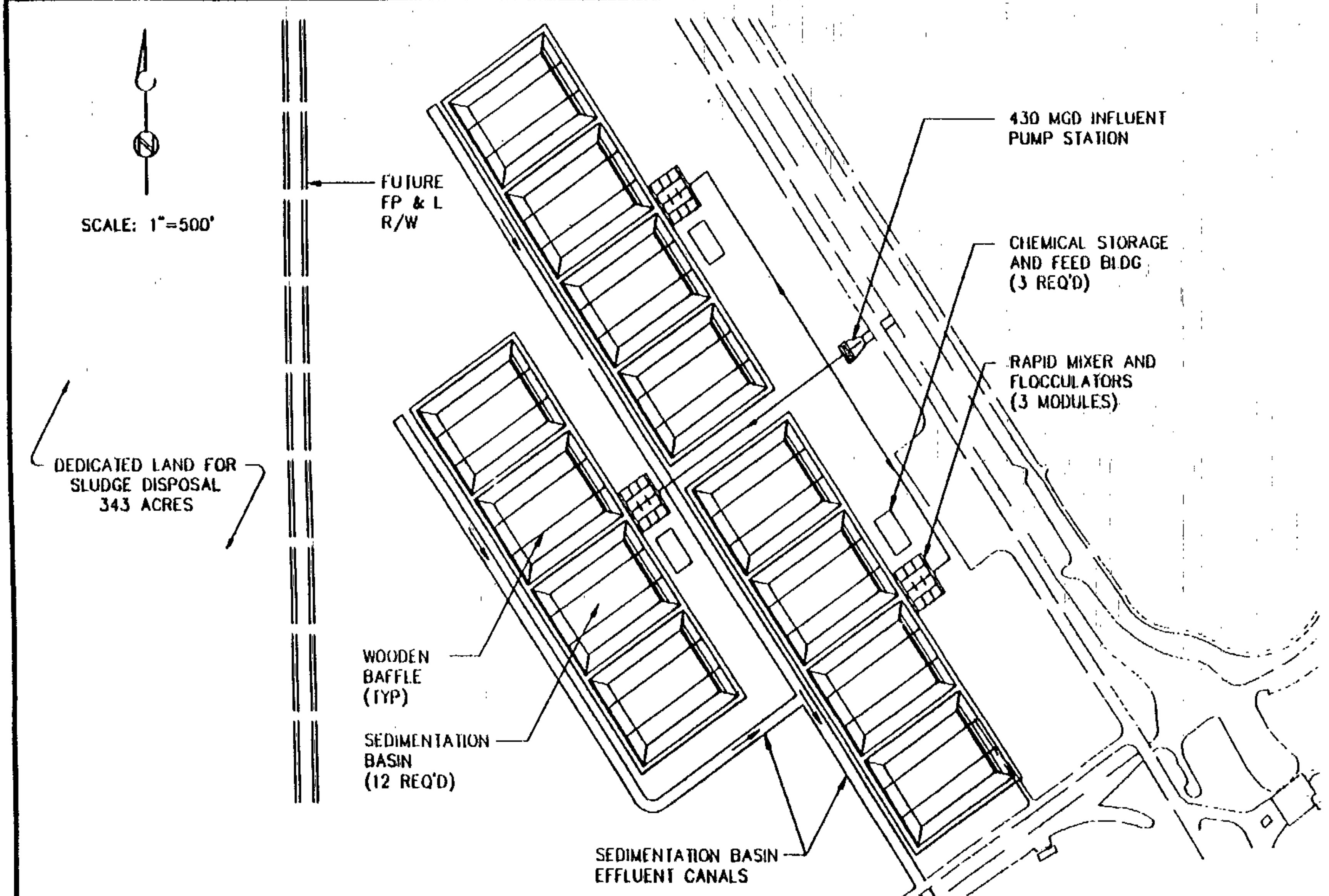
NOTE: SMALL DIAMETER PIPING NOT SHOWN FOR CLARITY

FIGURE 2-12.
SITE LAYOUT FOR CHEMICAL TREATMENT WITH WETLAND AT BASIN S-5A



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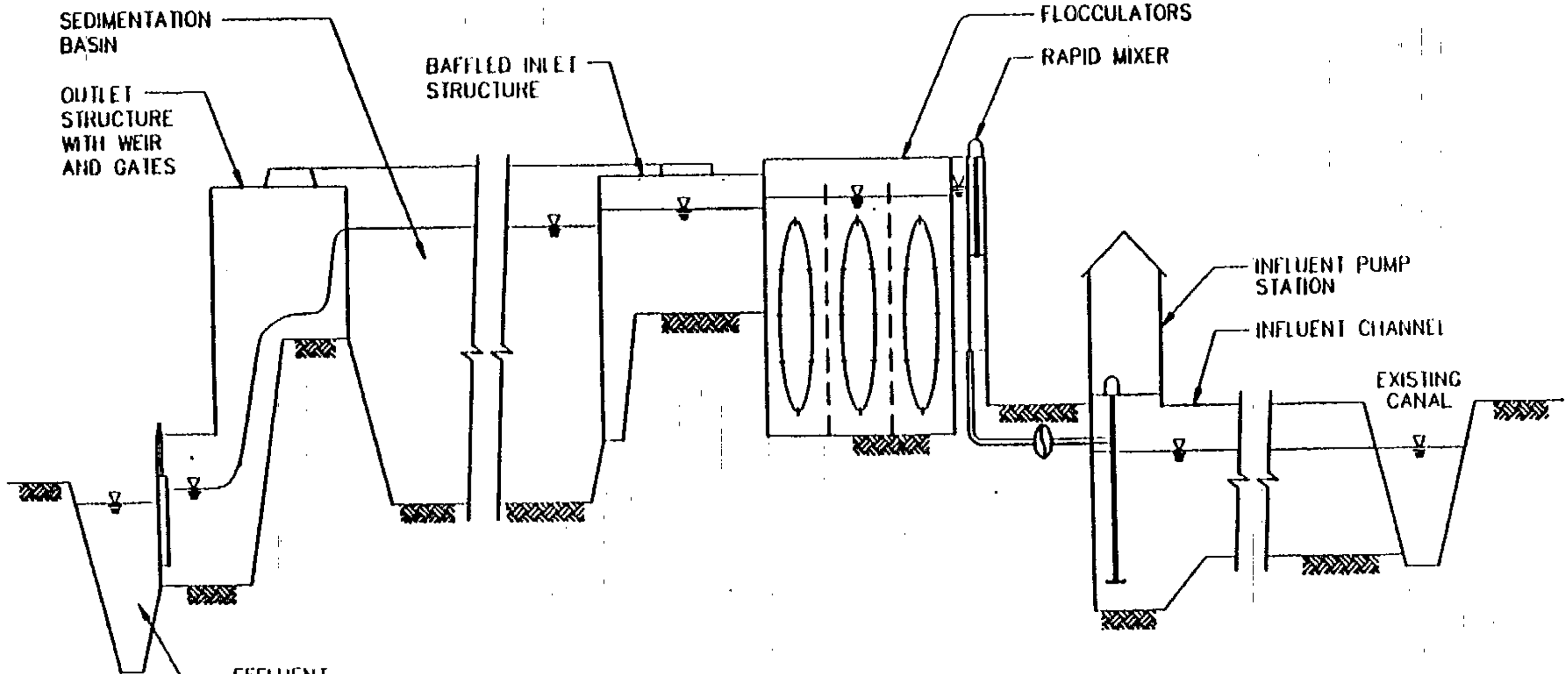
NOTE: SMALL DIAMETER PIPING NOT SHOWN FOR CLARITY

FIGURE 2-13.
SITE LAYOUT FOR CHEMICAL TREATMENT AT BASIN S-7



NOTE: TREATMENT UNITS ARE ELEVATED TO AVOID CONSTRUCTION BELOW THE GROUNDWATER TABLE

SCALE: 1"=100' HORIZONTAL
1"=10' VERTICAL

E:/7138/FIG2-14

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FIGURE 2-14.
CONCEPTUAL LONGITUDINAL SECTION, CHEMICAL TREATMENT

Table 2-12 Basis of Design for Chemical Treatment with Wetlands and Chemical Treatment

Item	Basin S-5A	Basin S-7
Basin data		
Flow, million gals		
Maximum annual	95,565	105,913
Minimum annual	41,627	28,817
Average annual	70,134	76,819
Phosphorus concentration, mg/l		
Maximum annual	0.234	0.140
Minimum annual	0.121	0.056
Average	0.187	0.094
TSS concentration, mg/l		
50th percentile	19	6
90th percentile	40	14
95th percentile	58	16
Plant data		
Percent of days on-line	33	71
Flow, mgd		
Maximum	570	430
Minimum	0	0
Average		
All days	114	130
When operating	347	183
Maximum year		
Average all days	152	217
When operating	462	306
Influent pumps		
Number of small pumps	1	1
Capacity each small pumps, gpm	30,000	30,000
Peak plant flow, mgd	570	430
Number of large pumps	4	4
Capacity each large pump, gpm	122,000	90,000
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33 percent $FeCl_3$	Liquid, 33 percent $FeCl_3$
Dose, as Fe, mg/l		
Average	10	10
Maximum	15	15
Pumps		
Number (1 spare)	5	4
Capacity, each, gpm	10	10
Storage tank		
Volume, gals	760,000	580,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2

Table 2-12 Basis of Design for Chemical Treatment with Wetlands and Chemical Treatment (continued)

Item	Basin S-5A	Basin S-7
Polymer		
Form	Liquid	Liquid
Dose, mg/l		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	5	4
Capacity, each, gpm	1	1
Solution tank volume, gals	10,000	10,000
Storage tank		
Volume, gals	1,600	1,200
Storage at peak feed rates, wks	2	2
Rapid mix tanks		
Number, in parallel	4	3
Volume, each, gals	3,300	3,300
Detention time at peak plant flow, sec	2	2
Mixer	Turbine	Turbine
Velocity gradient, sec^{-1}	750	750
Power input per tank, hp	14	14
Material of construction	Concrete	Concrete
Flocculators		
Number, in parallel	16	12
Stages per flocculator	3	3
Volume per stage, gal	247,000	247,000
Detention time per stage at peak flow, mins	10	10
Mixer	Horiz paddle	Horiz paddle
Velocity gradient, sec^{-1}		
Minimum	20	20
Maximum	90	90
Power input per stage, hp		
Maximum	15	15
Minimum	0.7	0.7
Material of construction	Concrete	Concrete

Table 2-12 Basis of Design for Chemical Treatment with Wetlands and Chemical Treatment (continued)

Item	Basin S-5A	Basin S-7
Sedimentation basins		
Number in parallel	16	12
Depth, ft	14	14.5
Width, each, ft[a]	275	275
Length, each, ft[a]	360	360
Weir length per basin, ft	1,650	1,659
Forward displacement velocity at peak flow, ft/min	1.0	1.0
Overflow rate at peak flow, gpd/ft^2	359	359
Detention time at peak flow, hrs	6	6
Weir rate at peak flow, gpm/ft^2	15	15
Dredges		
Number	1	1
Capacity, gpm	1,500	1,500
Material of construction	Earth	Earth
Stormwater treatment area		
Area, acres	6,200	Not applicable
Discharge pumping		
Peak flow, mgd	3,102	--
Number of pumps in parallel	74	--
Capacity per pump, gpm	30,000	--
Dedicated land disposal		
Sludge production, tons dry solids per year		
Maximum	9,984	9,833
Average	7,495	5,889
Maximum application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	7	7
Area per section, acres	50	49
Number of nurse tanks	7	7
Volume each nurse tank, gals	7,500	7,500
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	2	1
Spreading capacity each, gal/day	120,000	120,000
Land requirements, acres	6,717	470

[a] Excludes berm.

chemical treatment than it is for direct filtration. The higher chemical doses associated with chemical treatment also have more pronounced effects on treated water quality, although these effects are still minor.

Rapid Mixing

The design parameters for the chemical treatment rapid mix system are the same as the design parameters for direct filtration. The rapid mix tanks are sized to provide a nominal detention time of 2 seconds at peak flow, and the mixing intensities (G) of up to 750 sec^{-1} are provided by variable-speed turbine mixers.

Flocculation

In direct filtration systems, the objective is to form relatively small, tough floc which penetrate, but do not pass through, the filter bed. In contrast, chemical treatment systems are designed to produce large floc, since large floc are readily settled. The chemical treatment flocculators are therefore much larger than the direct filtration flocculators, thereby providing time necessary for significant floc growth. The current design assumes the flocculators are three-stage concrete tanks, with each stage providing 10 minutes nominal detention time at peak flow. The stages are separated by wooden or concrete baffles. The system uses tapered flocculation with mixing intensities of 90, 50, and 20 sec^{-1} in the first, second, and third stages, respectively. Mixing is provided by horizontal, reel-type paddles equipped with variable-speed drives.

Sedimentation

Sedimentation is carried out in large, earthen basins, enclosed by earthen berms with 3-to-1 horizontal-to-vertical sideslopes. The top of each berm is 15 feet wide to provide a crushed gravel road for vehicle access. The basins are sized to provide storage for 6 months of accumulated sludge and an overlying clear water layer of 12 feet in depth. The nominal forward water velocity (i.e., the scouring velocity) is limited to 1 foot per minute at peak flow to prevent resuspension of settled solids. The nominal detention time at peak flow is 6 hours. The overflow rate that derives from the above parameters is 360 gpd/sq ft at peak flow. Longitudinal redwood baffle walls are placed within the basins parallel to the direction of flow to foster plug flow conditions. Finger weirs, loaded at 15 gpm/ft at peak flow, provide effluent drawoff.

Sludge is allowed to accumulate and thicken within the basins for extended periods. Thickened sludge solids concentrations of about 7 percent are expected. During dry weather the thickened sludge is pumped from the bottom of the basins to the sludge disposal area by a floating dredge. Some water entrainment is expected to accompany dredging. Therefore, the concentration of the dredged material is expected to be about 5 percent.

Follow-On Wetland

A wetland follows the chemical treatment system in Basin S-5A. The wetland is designed to reduce phosphorus from 0.10 to 0.05 mg/l. The phosphorus loading on the follow-on wetland is essentially the same as the phosphorus loading on the STA in Basin S-7. Therefore, the area of the follow-on wetland for Basin S-5A is assumed to be the same as the Basin S-7 STA.

Note that there may be some advantages to locating the wetland in front of the chemical treatment instead of behind it. First, a leading wetland may be able to take up phosphorus faster than a follow-on wetland because it is treating water with higher phosphorus concentrations. Therefore, leading wetlands might be smaller than follow-on wetlands. Second, there is some concern that phosphorus previously accumulated in the soils of future wetland sites will be released during the initial years of operation. A follow-on chemical treatment system will be able to intercept "first flushes" of phosphorus from such a newly opened wetland. The current analysis assumes chemical treatment process will be located ahead of the wetland.

Sludge Treatment and Disposal

Table 2-12 shows estimated maximum and average annual sludge production estimates for Basin S-5A and S-7 chemical treatment systems. Sludge treatment and disposal facilities are sized to handle maximum annual sludge production rates. O&M costs are based on average sludge production rates.

Concerns about treatment and disposal of sludges from chemical treatment systems are the same as for sludges from direct filtration; namely, site life, protection of groundwater, and cost. Our analysis assumes that thickened sludges will be disposed on dedicated land as in direct filtration. Sludge loading rates and operating philosophies are the same as discussed previously for direct filtration systems. Sludge dewatering, with disposal of dewatered sludge in a landfill, remains a viable, but more costly, sludge treatment and disposal option.

Land Requirements

Table 2-13 summarizes land requirements for the basin-scale chemical treatment with a wetland and chemical treatment options. The chemical treatment with a wetland for Basin S-5A occupies about 15 times the acreage of the chemical treatment option for Basin S-7 because the chemical treatment with a wetland includes a 6,200-acre follow-on wetland.

Table 2-13 Land Requirements for Proposed Basin-Scale Chemical Treatment With Wetlands (Basin S-5A) and Chemical Treatment (Basin S-7)

Item	Land area, acres	
	Basin S-5A	Basin S-7
Influent pump station	0.2	0.2
Chemical addition and storage	0.7	0.5
Rapid mix and flocculation	3	2.5
Sedimentation basins	63	47
Dedicated land disposal	350	350
Operations building	0.4	0.4
STAs	6,200	-
Effluent pump station	0.3	-
Miscellaneous	100	70
Total	6,717	470

Costs

Table 2-14 summarizes capital costs for basin-scale chemical treatment with wetland and chemical treatment options. Capital costs were estimated with BACPAC and are expressed in December 1992 dollars for construction projects in South Florida. Because it involves two treatment systems (chemical treatment and wetlands) instead of one (chemical treatment alone), Basin S-5A chemical treatment with wetlands capital costs are more than double the capital costs of the Basin S-7 chemical treatment system. Appendix B provides further breakdowns of the capital cost estimate.

Table 2-14 Estimated Capital Costs for Basin-Scale Chemical Treatment with Wetlands (Basin S-5A) and Chemical Treatment (Basin S-7)

Item	Capital costs, million dollars[a]	
	Basin S-5A	Basin S-7
Contractor indirects	1.66	1.66
Yard development	0.93	1.24
Influent channel	0.20	0.20
Influent pump station	5.55	4.51
Water feed channel		
Chemical addition	1.11	0.56
Rapid mix	0.34	0.77
Flocculation	14.97	13.10
Sedimentation basins	5.41	4.59
Sludge holding tanks	0.35	0.35
Land disposal	1.00	0.77
Chemical treatment effluent channel	1.33	1.27
Wetland	22.03	N/A[b]
Wetland effluent pump station	7.20	N/A
Wetland effluent channel	15.62	N/A
Yard piping	4.30	2.65
Electrical/instrumentation	13.60	8.14
Operations building	0.78	0.78
Subtotal	99.80	40.59
Bond	1.00	0.41
Subtotal	100.80	41.00
Engineering at 15 percent	15.12	6.15
Construction contingency at 20 percent	20.16	8.20
Land purchase	21.83	1.10
Land contingency	12.01	0.39
Total capital cost	169.92	56.84

[a] December 1992 dollars.
[b] N/A = not applicable.

Table 2-15 summarizes O&M costs for the basin-scale chemical treatment with a wetland and chemical treatment options. O&M costs are broken down by treatment unit in spreadsheets contained in Appendix C. Appendix C also contains a list of assumptions used in deriving O&M costs. The cost of STA compliance monitoring is the major difference between chemical treatment with a wetland and chemical treatment O&M costs.

Table 2-15 Estimated Annual Operating and Maintenance Costs for Basin-Scale Chemical Treatment with Wetlands (Basin S-5A) and Chemical Treatment (Basin S-7)

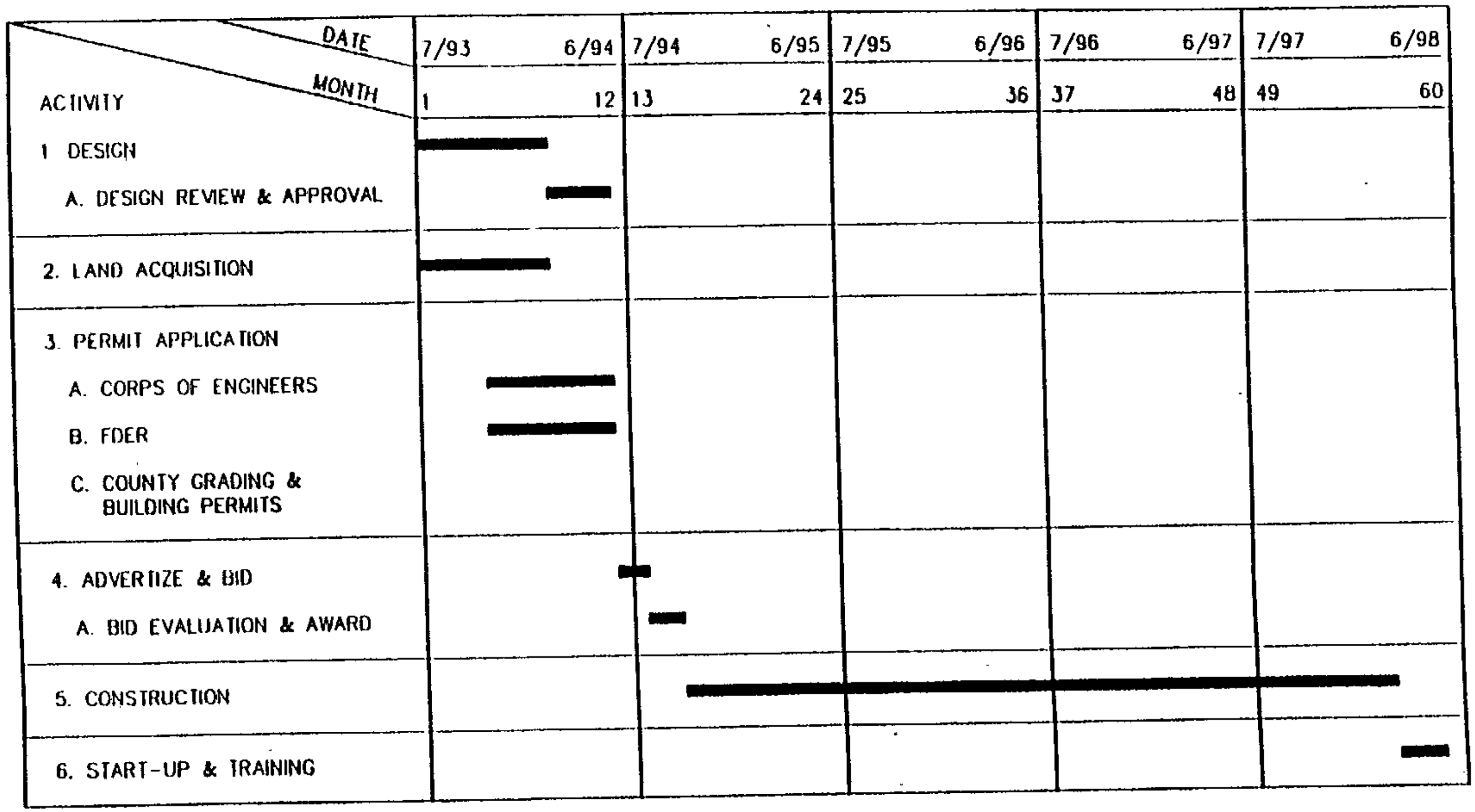
Item	O&M costs, million dollars[a] Basin S-5A	Basin S-7
Labor[b]	0.62	0.40
Materials[b]	0.25	0.09
Chemicals	0.71	0.80
Energy	0.47	0.34
Monitoring	1.56	0.16
Total	3.61	1.79

[a] December 1992 dollars.
[b] Does not include monitoring labor and materials; these costs are included separately under "monitoring."

The estimated present worth cost for the Basin S-5A chemical treatment with a wetland system is $205 million, based on Equation 2-13, a 20-year life, and an 8 percent discount rate. (Present worth analysis done over a 20-year period is the standard engineering present worth time-scale for constructed facilities. Other lengths of time may prove more appropriate during subsequent levels of present worth cost analysis.) The estimated cost per pound of phosphorus removal for this system is $128. The estimated present worth cost of the Basin S-7 chemical treatment system is $74 million, and the estimated cost per pound of phosphorus removal is $133.

Implementation Schedule

Tentative implementation schedules for the chemical treatment with a wetland alternative at Basins S-5A and the chemical treatment alternative at Basin S-7 are shown on Figures 2-15 and 2-16, respectively. Activities required for implementation of the projects include design, land acquisition, permit acquisition, advertising and bidding, construction, and start-up and operator training. The chemical treatment with a wetland would take 57 months to complete at Basin S-5A. Chemical treatment would take 53 months to complete at Basin S-7.



NOTE: START UP DOES NOT INCLUDE FOLLOW ON WETLAND

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FIGURE 2-15.
IMPLEMENTATION SCHEDULE FOR
MANAGED WETLAND AT BASIN S-5A

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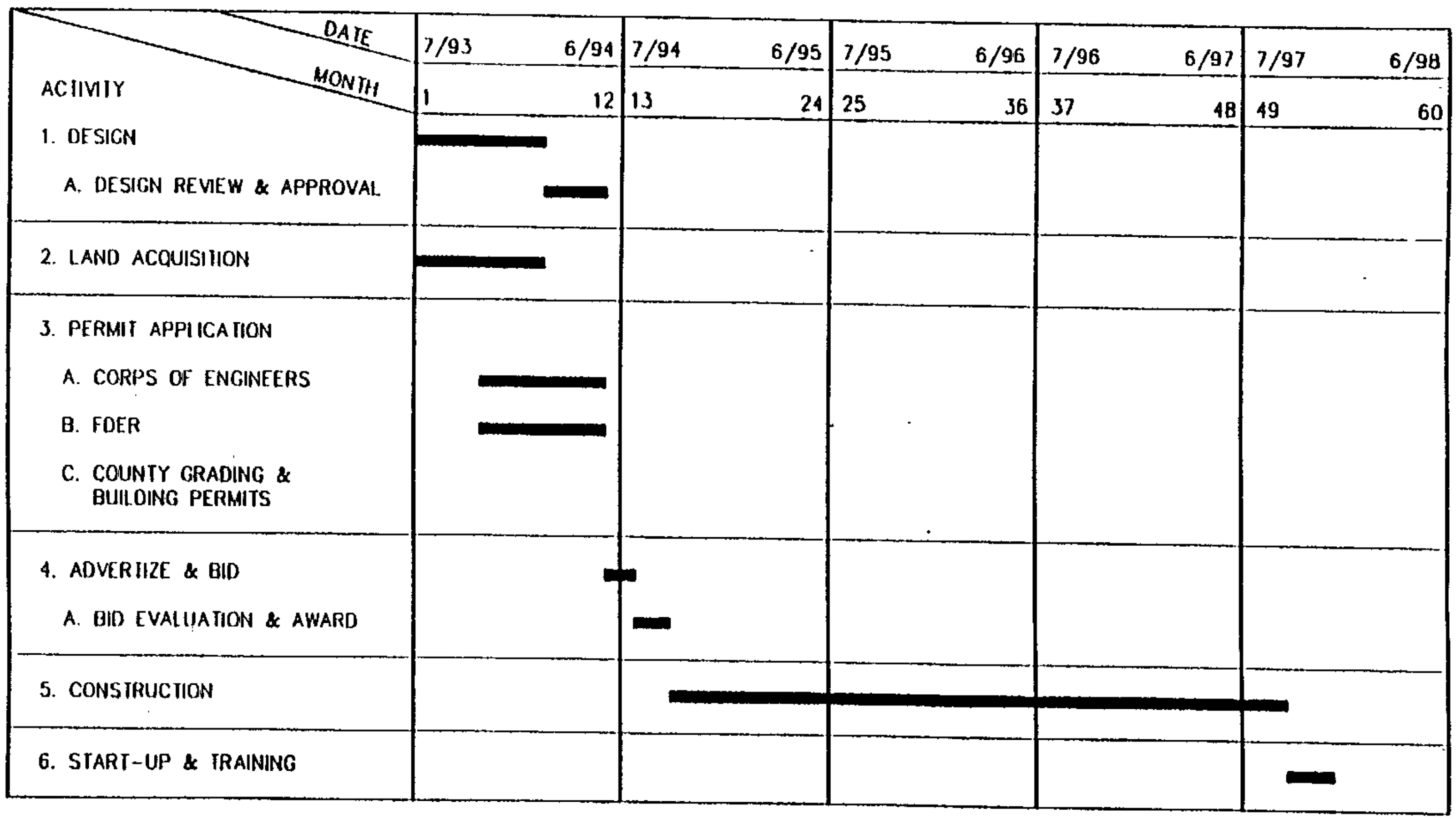

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FIGURE 2-16.
IMPLEMENTATION SCHEDULE FOR
CHEMICAL TREATMENT AT BASIN S-7

E:/7138/FIG2-16

NITROGEN REMOVAL CAPABILITIES OF THE TREATMENT ALTERNATIVES

While the focus of the EAA treatment program is on phosphorus removal, some have expressed concern that phosphorus might not be the nutrient limiting growth of nuisance plants in the WCA, or that if treatment removes sufficient phosphorus, that other nutrients (e.g., nitrogen) might become growth limiting. These concerns have raised the issue about the treatment alternative nitrogen (N) removal capabilities.

Examination of the District's water quality data base shows N to be present in EAA waters in moderate concentrations. Specifically, water samples collected at the Basin S-5A pump station during the period from 1974 to 1992 have averaged about 5.1 mg/l total N. Approximately 60 percent of the total N has been organic N, with nitrate-N (34 percent) and ammonia-N (8 percent) accounting for the rest. Approximately 20 percent of the organic N (or 12 percent of the total N) has been particulate N. Total nitrogen concentrations for samples collected at the Basin S-7 pump station have had lower N concentrations, averaging 3.3 mg/l for the period from 1974 to 1992. The N distribution is similar to that in Basin S-5A samples.

Treatment alternatives that use chemicals (e.g., direct filtration, chemical treatment) will remove particulate N with the same efficiency as they remove TSS. High TSS removals will, therefore, result in total N removals in the range of 12 percent.

Nitrate also can be removed by reduction with methanol (or other organic substrates) to nitrogen gas:

$$6NO_3 + 5CH_3OH = 5CO_2 + 3N_2 + 7H_2O + 6OH^- \tag{2-14}$$

The nitrogen gas then escapes to the atmosphere. Nitrate reduction (also known as denitrification) is routinely carried out in wastewater filters. Therefore, denitrification presents the potential for removing an additional 30 percent of the total N. The efficiency of removal is somewhat in question because the nitrate concentration in EAA waters is very low compared to nitrate concentrations in most municipal and industrial wastewaters, and reduction rates may be very slow. This question could be resolved by pilot testing.

Nitrogen can also be removed by wetlands principally through denitrification. However, at the depths of operation for the STAs, the opportunity for nitrification would be reduced. To promote nitrification, the current wetland system would need to include an overland flow section with flow depths of no more than 2 inches to provide sufficient oxygen transfer.

ECONOMIC EVALUATION OF BASIN-SCALE TREATMENT ALTERNATIVES

The basin-scale alternatives were rated on various economic impact criteria using the evaluation guidelines presented previously in Chapter 4 of the Final Report: Amendment No. 1 of the Everglades Protection Program Evaluation of Alternative Treatment Technologies (Brown and Caldwell Consultants, Contract C-3501 with the South Florida Water Management District, September 25, 1992). The multiplication of technology rating times weight factor yields the score for a technology against a criterion. Summation of the individual criterion scores yields the total economic evaluation score for the alternative.

For Basin S-5A, the technologies that were evaluated as part of Phase II are: (1) the stormwater treatment area (STA) system, as developed by Burns & McDonnell; (2) a chemical treatment with wetland system; and (3) a direct filtration system. For Basin S-7, the technologies that were evaluated as part of Phase II are: (1) the STA system, as developed by Burns & McDonnell; (2) a chemical treatment system (not followed by a wetland); and (3) a direct filtration system.

The estimated capital costs, O&M costs, and present worth costs for each basin-scale treatment alternative being considered are given in Table 2-16. The ratings for the economic criteria (other than revenue loss) are directly related to information given in this table.

Table 2-16 Present Worth Estimates of Everglades Treatment Alternatives

Item	Cost, million dollars[a]		
	Capital	O&M	Present worth[b]
Basin S-5A			
STA	118.2	3.53	152.8
Direct filtration			
High rate			
with dedicated land disposal[c]	88.8	2.12	109.6
with mechanical dewatering/landfill	98.6	2.98	127.8
Low rate[c]	107.7	2.49	134.1
Chemical treatment with wetlands[c]	169.9	3.61	205.3
Basin S-7			
STA	62.0	2.02	81.8
Direct filtration			
High rate[c]	34.4	1.43	48.4
Low rate[c]	44.0	1.64	60.1
Chemical treatment[c]	56.8	1.79	74.4

[a] December 1992 dollars.
[b] Present worth = capital cost + factor (O&M cost).
Factor, based on 20-year equipment life and 8 percent interest = 9.8181.
[c] Costed for disposal of thickened sludge on dedicated land.

In addition to capital, O&M, and present worth costs, the alternatives were evaluated on the revenue loss anticipated if each alternative is implemented. The assumption is that total revenue loss due to the implementation of the STA systems consists of:

1. Total change in sales (direct, indirect, and induced).
2. Total change in earnings (direct, indirect, and induced).
3. Total change in property taxes.
4. Total change in state corporate taxes.

Revenue loss values for these four areas were given in Table 8-9 of the Hazen and Sawyer Draft Final Report: Evaluation of the Economic Impact From Implementing the Marjory Stoneman Douglas Everglades Restoration Act (SFWMD Contract No. C-3172, July 18, 1992). The values given in Table 8-9 of the Hazen and Sawyer report represent the sum for implementation of all four STA systems planned for the EAA. It is important to note that the Hazen and Sawyer report links the current type of crop growth, in the actual areas where the STAs are expected to be located, with the revenue loss values.

These total revenue loss values for the STA systems vary from year to year as construction is initiated and completed. For this analysis, the total revenue loss values for the year 1998 (construction of STAs assumed to be underway at this time) from the Hazen and Sawyer report along with an estimate of the total amount of STA land area required were used to calculate an approximate annual revenue loss per acre value. The total land area given in Table 8-9 of the Hazen and Sawyer report is 31,353 acres, which represents "acres actually planted." The Burns & McDonnell conceptual design report calls for a total of 35,167 acres, which represents "acres acquired," and also includes supplemental land which is required for the STA systems but is not actually a part of the treatment areas. In this analysis, the Burns & McDonnell "acres acquired" number was used to determine an approximate annual revenue loss per acre value. The revenue loss value found using this procedure is $2,373 per acre per year. This unit revenue loss value was then multiplied by the approximate acreage required for the other alternatives to determine an estimated revenue loss if a particular alternative is implemented. The results of these calculations are presented below in Table 2-17. The ratings subsequently given to each alternative for the revenue loss criteria are proportional to the total annual revenue loss values calculated.

Table 2-17 Estimated Revenue Loss for Basin-Scale Treatment Alternatives

Basin	Acres	Total annual revenue lost, million dollars
Basin S-5A		
STA	12,200	28.95
Chemical treatment with wetlands	6,717	15.94
Direct Filtration	424	1.01
Basin S-7		
STA	6,200	14.71
Chemical Treatment	470	1.12
Direct Filtration	186	0.44

The economic evaluation of basin-scale treatment alternatives is summarized in Table 2-18. Note that high-rate direct filtration with dedicated land disposal of sludge was used to rate the direct filtration options in both basins. This analysis indicates that the direct filtration options are economically superior to any of the other alternatives being considered for both Basin S-5A and Basin S-7.

Table 2-18 Economic Evaluation of Basin-Scale Treatment Technologies

Criterion	Criterion weight	Basin S-5A			Basin S-7		
		STA	Chemical treatment with wetlands	Direct filtration	STA	Chemical treatment	Direct filtration
Capital cost	10	5	2	7	5	6	9
Operation and maintenance cost	5	5	6	9	5	7	9
Revenue loss	5	1	4	10	1	8	10
Present worth	15	5	1	9	5	6	9
TOTAL SCORE FOR ECONOMIC EVALUATION:		155	85	300	155	225	320

NONECONOMIC EVALUATION OF BASIN SCALE TREATMENT ALTERNATIVES

This section presents a summary of the Phase II noneconomic evaluation of the treatment technologies being considered for Basins S-5A and S-7. Criteria used for this evaluation were presented previously in Chapter 4 of the Final Report: Amendment No. 1 of the Everglades Protection Program Evaluation of Alternative Treatment Technologies (Brown and Caldwell Consultants, Contract C-3051 with the South Florida Water Management District, September 25, 1992). These noneconomic criteria were divided into three categories: performance, environmental, and other criteria. Weights were assigned to reflect the relative importance of each criterion.

For Basin S-5A, the technologies which were evaluated as part of Phase II are: (1) the stormwater treatment area (STA) system, as developed by Burns & McDonnell; (2) a chemical treatment with wetland system; and (3) a direct filtration system. For Basin S-7, the technologies which were evaluated as part of Phase II are: (1) the STA system, as developed by Burns & McDonnell; (2) a chemical treatment system (not followed by a wetland); and (3) a direct filtration system.

Included in this section is a restatement of each criterion description and guidelines for ratings (as presented in the Final Report, Amendment No. 1), as well as the reasoning supporting the final assignment of ratings. Each technology was rated on a scale of 1 to 10 against each criterion. The multiplication of the technology rating times the weighting factor yields the score for a technology against the criterion. Summation of the individual criterion scores yields the total noneconomic evaluation score for the technology.

Table 2-19 presents the overall noneconomic score for each basin-scale technology considered. As shown in this table, direct filtration rates the highest on the performance criteria for both basins, while the STA systems rate the lowest for this set of criteria. Under the environmental criterion category, however, the STA systems rated the highest in both basins. The direct filtration systems have the highest overall noneconomic rating for both basins.

Table 2-19 Noneconomic Evaluation of Basin-Scale Treatment Technologies

Criteria	Criteria Weight	Basin S-5A STA	Basin S-5A Chemical treatment with a wetland	Basin S-5A Direct filtration	Basin S-7 STA	Basin S-7 Chemical treatment	Basin S-7 Direct filtration
Performance Criteria							
Phosphorus removal capability	10	4	5	10	5	5	10
Implementation schedule	8	2	3	7	2	4	10
Hydroperiod impact	6	7	6	5	7	6	5
Previous applications	5	6	7	10	6	7	10
Reliability	3	5	6	10	5	6	10
Flexibility	3	5	6	9	5	7	9
Permitting requirements	3	8	3	6	8	3	6
Subtotal, performance criteria:		182	190	311	192	201	335
Environmental criteria							
Habitat value	6	9	7	5	9	6	5
Downstream water quality	4	8	6	7	8	6	7
Drinking water supply	4	6	6	5	6	5	5
Ground and surface water	2	5	5	5	5	5	5
Impact on C & SF Project	1	6	7	10	6	10	10
Energy utilization	1	5	1	2	5	3	4
Cultural and archeological	1	5	6	9	5	7	9
Construction impacts	1	6	8	10	8	10	10
Subtotal, environmental criteria:		142	122	119	144	120	121
Other criteria							
Land area requirements	2	6	8	10	8	10	10
Operation and maintenance	2	7	7	5	7	6	5
Employment	1	1	2	10	1	9	10
Public health and safety	1	7	5	6	7	5	6
Local resource availability	1	10	5	6	10	5	6
Subtotal, other criteria:		44	42	52	48	51	52
TOTAL SCORE FOR NONECONOMIC EVALUATION:		368	354	482	384	372	508

PERFORMANCE CRITERIA

The basin-scale technologies were rated on the following performance criteria: phosphorus removal capability, implementation schedule, hydroperiod impact, previous application of technology, reliability, flexibility, and permitting requirements. Each criterion evaluation is presented below.

Phosphorus Removal Capability

Criterion Weight: 10

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
4	5	10	5	5	10

This criterion measures the capability of each technology to satisfy the SWIM Plan requirement of reducing the total phosphorus load to the Everglades. If the technology reduces phosphorus consistently, it is rated higher than a technology that cannot achieve phosphorus reduction dependably. The rating guidelines that were established for this criterion in Chapter 4 of the Final Report, Amendment No. 1 were modified because none of the technologies is designed to meet or can meet the phosphorus reduction target value on a monthly average. The phosphorus removal design objective for each of the proposed alternatives currently is regarded as a long-term (10-year average) goal of 0.05 mg/l phosphorus. The following are the revised guidelines for rating the proposed treatment alternatives: if the proposed technology is capable of reducing phosphorus loads by the required percentage on a predictable and consistent basis, 8 to 10; if the proposed technology is capable of reducing phosphorus loads by the required percentage routinely, but performance is difficult to predict, 5 to 7; or, if the proposed technology is marginally capable of reducing the phosphorus loads by the required percentage on a long-term basis, 1 to 4. (This represents a change from the Final Report: Amendment No. 1 rating guidelines to update the performance criteria to reflect how compliance measurement is currently being proposed.)

On the basin scale, an STA system would be only marginally capable of reducing the phosphorus load to the Everglades on a long-term basis. The primary reason that the capability of a STA is marginal is that there is no way to control the processes with which a wetlands system removes or releases phosphorus. The direct filtration systems were rated a 10 for this criterion in both basins because they would provide a very high degree of process control. This aspect increases the consistency and predictability of phosphorus removal for direct filtration systems with respect to the other alternatives. Because the chemical treatment systems would provide a moderate amount of process control, they were rated between the other alternatives for each basin.

Implementation Schedule

Criterion Weight: 8

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
3	4	7	2	4	10

This criterion evaluates the capability of the proposed technologies to achieve interim phosphorus concentrations to the Everglades Protection Area by July 1, 1997. To rate each technology, it was necessary to assess when various system elements could be brought on-line. Technologies that can be implemented quickly and placed into operation prior to the 1997 deadline were rated higher than those that cannot. The established rating guidelines for this criterion are as follows: if all elements of the alternative can be implemented prior to 1997, 8 to 10; if all elements of the alternative are implementable by 1997, 5 to 7; if minor elements of the alternative are not implementable by 1997, 3 to 4; or, if major elements of the alternative are not implementable by 1997, 1 to 2.

Acquiring farmland will require negotiations and, if necessary, the condemnation of large land areas if an STA is utilized for either basin. Therefore, land acquisition is seen as the primary reason that the construction of the STA systems cannot be completed by 1997. Additionally, once construction of an STA system is completed, it is expected that there will be an initial period (up to several years) when the SWIM Plan objectives will not be met because of initial flushing of phosphorus from the agricultural soils. The chemical treatment system designs for both basins are projected to still have some minor elements of construction as well as start-up and training after the implementation deadline. However, the wetlands associated with the chemical treatment system of Basin S-5A will require some time to allow the initial phosphorus from the former agricultural lands beneath it to be flushed. The interim phosphorus concentration required by the SWIM Plan will not be achieved until this occurs. The chemical treatment system design for Basin S-7 is not followed by a wetlands and, therefore, will result in less disturbance of the sediment and less initial flushing of phosphorus. The direct filtration system of Basin S-5A should still be in the construction phase after the 1997 deadline, and will still require start-up and training. These activities are expected to be completed in mid-1998. However, once the direct filtration system is put on-line, the phosphorus removal objectives of the SWIM Plan can be met immediately. The direct filtration system of Basin S-7 should be fully implemented and achieving the SWIM Plan phosphorus removal objective by the July 1, 1997 deadline.

Hydroperiod Impact

Criterion Weight: 6

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
7	6	5	7	6	5

The quantity, distribution, and timing of water flow to the EPA is critical to maintaining and restoring native floral and faunal communities. The SWIM Plan requires that actions be taken to restore hydroperiod in the EPA in conjunction with measures to reduce phosphorus loads. This criterion measures the capability of the proposed alternatives to maintain hydroperiod in the EPA. The established rating guidelines are as follows: if an alternative results in a significant improvement to the hydroperiod of the EPA, 9 to 10; if improvement is seen, 7 to 8; if no changes in flows to the EPA occur, 5 to 6; if significant seasonal changes to flows entering the EPA are expected due to the implementation of an alternative, 3 to 4; or, if significant year-round changes to flows entering the EPA are expected, 1 to 2.

Water storage prior to the Everglades positively affects the downstream hydroperiod because it allows large agricultural drainage flows to be equalized. When operated as designed, however, the storage capacity of the STA systems is minimal when compared with total drainage flows of the EAA, and therefore will produce little equalization. Occasionally, during drought periods when water levels in the Everglades are low and the evapotranspiration rate over the large water surface area is high, an STA could have an adverse effect on the hydroperiod because it may deprive downstream areas of needed water. An STA cannot be allowed to dry out or oxidation reactions may take place, allowing phosphorus to be released and flushed downstream when flows resume. The storage capacity of the STA systems is also limited by the fact that the STA systems have a set shallow design depth that cannot be exceeded or the phosphorus removal capability may be compromised. A direct filtration system will provide negligible water storage, and therefore should not affect the flows or the hydroperiod of the EPA. Both chemical treatment systems will provide an insignificant amount of storage capacity, although more than the direct filtration system.

Previous Application of Technology

Criterion Weight: 5

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
6	7	10	6	7	10

It is important that the alternative selected have documented evidence that it will be successful in satisfying the performance objectives of the SWIM Plan. A technology with successful previous applications at full scale on stormwater or agricultural drainage will have the best documented evidence and, therefore, is rated the highest against this criterion. The established rating guidelines for this criterion are as follows: if the technology has been successfully applied at full scale for the treatment of stormwater or agricultural drainage, 10; if the technology has been successfully applied at full scale in water or wastewater treatment applications, 7 to 9; if the technology has been successfully field tested at full scale for the treatment of stormwater or agricultural drainage, 5 to 6; if the technology has been demonstrated through pilot testing in the field, 3 to 4; or, if the technology has been demonstrated only at bench scale in the laboratory, 1 to 2.

An STA system of the size proposed has never been applied to stormwater or agricultural drainage at sizes and loading rates comparable to those required by the SWIM Plan for the protection of the Everglades. Direct filtration systems used to treat agricultural drainage have been successfully applied in Germany for over 15 years. The agricultural stormwater being treated in the German facility is close to the same phosphorus concentration as is present in Basin S-5A flows. The only difference between the German experience and the direct filtration system designs proposed for the Everglades is that, for the basin scale, both low- and high-rate filtration systems are being considered, whereas in the German application, low-rate filtration is used. Chemical treatment with a wetlands system and chemical treatment with sedimentation have been implemented at wastewater treatment facilities more than individual STA systems, and therefore, they were rated higher on this criterion.

Reliability

Criterion Weight: 3

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
5	6	10	5	6	10

The reliability of the treatment technology selected is important to its ability to consistently meet the long-term performance objectives of the SWIM Plan. Factors considered in evaluating each technology with respect to reliability include: (1) provision for back-up treatment capability, if needed; (2) sensitivity to changes in hydrologic conditions; (3) dependence on proper operation and maintenance procedures being performed; (4) dependence on BMPs and FTAs by growers, and (5) the number of treatment units proposed for the implementation of the technology at the scale of the application being considered. For this evaluation, the reliability of an alternative was measured against the anticipated reliability of an STA system as the Base Case Alternative. The established rating guidelines for this criterion are as follows: if the technology provides a higher degree of reliability than the Base Case Alternative, 6 to 10; if the degree of reliability is the same as the Base Case Alternative, 5; or, if the technology has a lower degree of reliability than the Base Case Alternative, 1 to 4.

Since the STA system is the Base Case Alternative, it was rated a 5 for both basins. The direct filtration systems will be designed to have enough back-up or redundancy to be very reliable. It is assumed that operators with skills consistent with each of the technologies will be employed. Based on full-scale operating experience in Germany, direct filtration systems are very reliable when used to remove phosphorus from agricultural drainage. An STA system may not be able to meet the performance objectives of the SWIM Plan reliably during its start-up period. After start-up, an STA system is estimated to be only 50 percent reliable. Because of the ability to achieve some process control, any kind of chemical treatment with sedimentation should be more reliable than any system which utilizes only a wetland. However, the increased influent phosphorus concentration in Basin S-5A should reduce the reliability of the chemical treatment with wetlands system when compared with the chemical treatment system of Basin S-7. The presence of a large, and basically uncontrollable, sedimentation system reduces reliability. Sediments could be partially resuspended by wave action or by the temperature changes. Metals and phosphorus might be released from the sediments by changes in pH.

Flexibility

Criterion Weight: 3

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
5	6	9	5	7	9

This criterion measures the flexibility of the alternatives in terms of their capability to accommodate future changes in loading rates and/or performance requirements. A measure of the flexibility of a technology is its ability to be adapted to changing future conditions to achieve the most cost-effective means of meeting the performance objectives. Further, if the proposed phosphorus limit is not sufficient to adequately protect the Everglades, additional treatment to remove other constituents may be necessary in the future. This criterion was rated based on the flexibility of the particular alternative as measured against the flexibility of an STA system as the Base Case Alternative. The established rating guidelines for this criterion are as follows: if the technology has a higher degree of flexibility when compared to the Base Case Alternative, 6 to 10; if the degree of flexibility is the same as the Base Case Alternative, the technology should rate a 5; or, if the alternative has a lower degree of flexibility when compared to the Base Case Alternative, 1 to 4.

Direct filtration would be the most flexible alternative for both basins because it can be expanded fairly easily. The STA and chemical treatment with a wetlands system would be harder to expand because such systems require large amounts of land. Also, if performance requirements are not being met because of changes in loading rates or other factors, a system that uses chemicals can be more easily adapted by changing the chemical addition (dosage amount, type, etc.) whereas an STA may not be able to handle a change in loading rate without an expansion. The scoring recognizes that systems which use chemicals would not be able to remove nitrogen compounds to the degree provided by a wetlands system.

Permitting Requirements

Criterion Weight: 3

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
8	3	6	8	3	6

This criterion measures the anticipated regulatory permitting requirements of each alternative. The alternatives which require only construction permits are the most preferable with respect to this criterion (rated in the range of 8 to 10). An alternative that requires operating permits is less desirable because of the ongoing regulatory monitoring and compliance activities that must be accomplished. If an alternative requires waivers or exemptions, it is seen as the least desirable from a permitting perspective (rated in the range of 1 to 2). In assigning ratings to technologies, the anticipated difficulty in obtaining permits was also considered.

Fully defining the composition of the sludge created from any of the precipitation processes being considered is seen as the requirement which may hold up the permitting of any technology which utilizes chemical treatment. STAs do not generate identifiable sludges and are, therefore, not subject to the same regulations. Additionally, with the chemical treatment systems, the impact to groundwater will need to be fully assessed before permitting.

Permit applications for the conceptual designs of the STAs have been filed with the FDER. Currently, an Intent to Issue a Permit has been given to the District by this State agency. Therefore, the permitting process will be inherently easier for the STA systems because it has been initiated already. The permitting application process has not been initiated for any of the other alternatives being considered, and it is assumed that there is more involved in obtaining the necessary permits.

ENVIRONMENTAL CRITERIA

The basin-scale technologies were rated on these environmental criteria: habitat value; downstream water quality; drinking water supply; ground and surface water hydrology; impact on C&SF Project; energy utilization; cultural and archeological resources; and construction impacts.

Habitat Value

Criterion Weight: 6

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
9	7	5	9	6	5

Some technologies impact habitat value in the Everglades Agricultural Area (EAA) more than others as land is taken out of production and used for other purposes. This criterion measures the anticipated change that an alternative would have on habitat value in the EAA when compared with current conditions. For this criterion, if habitat value increases over current conditions, the technology is rated in the range of 6 to 10. If habitat value does not change, the technology is rated 5. If habitat value decreases over current conditions, the technology is rated 1 to 4.

Direct filtration systems were rated a 5 in both basins because the amount of land such systems require is insignificant compared with the other alternatives. Technologies that use wetlands would provide an increase in habitat value in the EAA over present conditions, since currently the land is used for agriculture and is generally disturbed. An STA system would create the greatest increase in habitat value in the EAA because it uses the most land area. With the chemical treatment with wetlands system in Basin S-5A, the habitat value should be increased relative to a direct filtration system. For Basin S-7, the chemical treatment alternative rating was lower than the chemical treatment with wetlands system of Basin S-5A, recognizing that the wetlands will provide a substantial amount of additional land which can be used as wildlife habitat. A sedimentation basin will also provide a fairly large water surface area and should increase habitat value over the direct filtration system.

Downstream Water Quality

Criterion Weight: 4

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
8	6	7	8	6	7

Reducing phosphorus discharges to the Everglades is a primary objective of the SWIM Plan. Other related water quality issues are also important to the evaluation of technologies. Other constituents may become a problem in the Everglades. Shifts in water quality and changes in concentrations of trace elements, such as heavy metals, could also become water quality concerns if some technologies are implemented. This criterion measures the potential for impacts on downstream water quality resulting from implementation of the different technologies. If the implementation of a technology has the potential to enhance downstream water quality, the rating is 6 to 10. If the implementation of the technology is anticipated to have little impact on downstream water quality, the technology is rated a 5. If the implementation of the technology has potential to downgrade downstream water quality, the technology is rated 1 to 4.

Advantages and disadvantages exist, in terms of impact on downstream water quality, for all three alternatives for both basins. All forms of chemical treatment would put either chlorides or sulfates and possibly more sodium into the treated effluent than existed in the influent, and this would be somewhat negative in terms of downstream water quality. However, the concentrations of these constituents will not be high, and the effects to downstream species should be negligible. STA systems and the chemical treatment with wetlands system in Basin S-5A can be expected to remove some nitrogen from the water through the natural nitrification/denitrification processes which will occur. Denitrification can be designed into the direct filtration system to remove some of the nitrogen in the EAA runoff. The STA systems, from the standpoint of taking out more nitrogen than the other alternatives and putting less chlorides and sulfates into the treated effluent, are rated higher than the other alternatives being considered. Because the alternatives with sedimentation basin systems will require a higher chemical dose than the direct filtration systems, they will add more chlorides and sulfates to the downstream water. All alternatives will remove metals to some extent. It is usually considered beneficial to remove metals. However, there has been discussion on the consequences of high metals removals, when trace amounts are needed downstream. With the STAs, less stripping out of trace metals and other essential nutrients should occur; although, this system may not provide the desired downstream water quality from the standpoint of phosphorus removal. The STA generally would be expected to produce a water quality similar to that discharged from WCA-2A and thereby be more compatible with the Everglades system.

It is recognized that a comprehensive treated water quality analysis (including ecological effects) would be necessary before full-scale implementation of any of the technologies discussed.

Drinking Water Supply

Criterion Weight: 4

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
6	6	5	6	5	5

It is not anticipated that any of the technologies being considered for protection of the Everglades will have an adverse impact on the quality of water currently being used for drinking water supply. However, the alternatives have different impacts on the quantity of water available to the lower east coast of Florida for water supply purposes. This criterion measures the impact of a technology on the quantity of water available for drinking water supply. For this criterion, if an increase is anticipated in the quantity of water available for drinking water supply, the technology is rated 6 to 10. If no change is anticipated in the quantity of water available for drinking water supply, the alternative is rated 5. And, if a decrease is anticipated in the quantity of water available for drinking water supply, the alternative is rated 1 to 4.

This criterion is a quantity issue only, and the emphasis of drinking water supply is on surface water storage. If water can be held for a longer period of time before it is released, opportunity to satisfy drinking water supply requirements is better. An STA system will have more evapotranspiration losses than any of the other alternatives because of the large water surface area associated with it. However, with the storage that is provided with an STA system or the chemical treatment with a wetlands system, some water will be released more slowly into the Everglades, and therefore, less of it is removed from supply by immediately entering the ocean. The storage capacity of an STA system is very small when compared with the amount of drainage that the EAA experiences during storm events and should provide minimal benefits to the drinking water supply. With a direct filtration system, basically all water that comes in, goes out immediately. The chemical treatment system in Basin S-7 has no wetland attached to it and, therefore, has less storage capability relative to the chemical treatment with a wetland in Basin S-5A.

Ground and Surface Water

Criterion Weight: 2

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
5	5	5	5	5	5

For this criterion, if the particular alternative has the potential for positive impact on local or regional hydrology, the alternative is rated 6 to 10. If there is no anticipated impact on local or regional hydrology, the alternative is rated a 5. If there is a potential for negative impact on local or regional hydrology, the rating is 1 to 4.

Storage would have some positive impact on the local or regional hydrology. This would be particularly true during drought periods, when additional water could be made available to the Everglades. In this regard, direct filtration systems would have no impact, since they provide negligible storage. Even with the inclusion of a follow-on wetlands, the chemical treatment systems are considered to offer negligible amounts of water storage capability. An STA system would provide a small amount of storage when compared with the two other alternatives being considered. However, this slight positive impact is evened out due to the large area and depth of water requirements of the STA systems, causing the potential negative impacts in the form of seepage and elevated groundwater table in the surrounding area.

Impact on C&SF Project

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
6	7	10	6	10	10

The alternative selected must be consistent with the objectives and authorizations of the Central and South Florida (C&SF) Project being administered by the U.S. Army Corps of Engineers. An alternative may impact the flood protection and/or water supply purposes of the Project. Significant impacts may require Congressional action. This criterion measures the degree to which each alternative impacts the C&SF Project as currently authorized and operated. If no significant changes to the operational plan of the C&SF Project will occur as a result of implementation of the alternative, the recommended rating range is 8 to 10. If potentially significant but implementable changes to the operational plan of the C&SF Project are likely to occur, then a rating in the range of 4 to 7 is used. If Congressional reauthorization is required to implement an alternative, then a rating of 1 to 3 is used.

A direct filtration plant will only pull out and then quickly put back water into the canals and have no significant storage of water. Therefore, a direct filtration plant should not have any appreciable impacts on the C&SF Project. The chemical treatment system of Basin S-7 should also have minimal impact on the C&SF Project for the same reasons. Since the chemical treatment with wetlands and the STA systems involve some storage of water, these alternatives will require more monitoring by the Army Corps of Engineers and may involve more operational changes to the C&SF Project. However, changes to the operational plan of the C&SF Project required to accommodate these alternatives are expected to be implementable.

Energy Utilization

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
5	1	2	5	3	4

The SWIM Plan, as currently proposed, will require significant pumping of flows to, and possibly from, the STAs. Energy use, while not a critical factor, is still an important consideration in the evaluation of the alternatives. This criterion measures the anticipated energy utilization of an alternative compared with an STA system as the Base Case Alternative. If an alternative has the energy utilization of the Base Case Alternative, it is rated 5. If the anticipated energy utilization of a technology is below that of the Base Case Alternative, the rating is 6 to 10. If the anticipated energy utilization is in excess of the Base Case Alternative, it is rated 1 to 4.

By criterion definition, the STA was given a rating of 5. In Basin S-5A, the chemical treatment with a wetland system would use about twice the energy of an STA system, and, therefore, a rating of 1 was given to the chemical treatment with wetlands. A direct filtration system is only slightly lower in energy use than the chemical treatment with wetlands, and therefore, a rating of 2 was given. Although they are still higher, when compared to Basin S-5A, the energy use of the other alternatives for Basin S-7 are closer to the energy use of an STA system in Basin S-7 than they are in Basin S-5A.

Cultural and Archeological

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
5	6	9	5	7	9

The probability of significant cultural or archeological resources being found intact on agricultural lands is very low. Consequently, the potential for treatment projects constructed in the EAA to impact such resources is also very low. However, the history of Indian culture in south Florida and the presence of Indian reservations to the south and west of the EAA suggests that potential impacts on cultural and archeological resources should be included in the technologies evaluation process. This criteria measures the potential of an alternative to impact cultural and archeological resources. If no impact on cultural or archeological resources is anticipated, the technology is rated a 10. If the impact on cultural or archeological resources is possible, but not probable, the technology is rated 5 to 9. If the impact on cultural or archeological resources is probable, a rating of 1 to 4 is given.

In rating this criterion, it was assumed that the ratings are proportional to land area required for the alternative. Further, it was assumed that Indian artifacts are spread out uniformly on the EAA land. The design land requirements are given below in Table 2-20 (the land areas given for the STA systems are from the Burns & McDonnell conceptual design). All alternatives for both basins were rated between 5 to 9, because, if anything of cultural or archeological significance had been located on the land, farming activities probably assure no such objects remain. Since the direct filtration systems require the least amount of land, they were rated a 9 in both basins. The other alternatives were rated between 5 and 9 based on the amount of land they require relative to the direct filtration system land requirements for that particular basin.

Table 2-20 Design Land Area Requirements (Acres)

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
12,200	6,717	424	6,200	470	186

Construction Impacts

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
6	8	10	8	10	10

Construction of treatment units at the scale proposed for protection of the Everglades will require clearing large land areas. In addition to the upheaval of sediments containing high concentrations of nutrients, significant phosphorus could be released to the Everglades if soils are drained and allowed to refill. This criterion assumes that the land area disturbed and, therefore, able to contribute to short-term releases of nutrients into the Everglades, is directly proportional to the total land required for implementation of a technology. The larger the area of land disturbance, the greater the potential for short-term nutrient impacts downstream. The established rating guidelines for this criterion are as follows: less than 5,000 acres, 10; 5,000 to 10,000 acres, 8; 10,000 to 20,000 acres, 6; 20,000 to 30,000 acres, 4; 30,000 to 50,000 acres, 2; or, greater than 50,000 acres, 1.

The calculated land areas for each alternative being considered for Basin S-5A and Basin S-7 were given previously in Table 2-20 of this section. The guidelines, established previously and given above, indicate what each alternative should be rated based on its required land area; however, it should be noted that these ratings are not in direct proportion to the relative land area requirements for each alternative. For example, for both basins, the STA design requires more than 25 times the amount of land as the direct filtration system, but the rating guideline does not reflect this.

OTHER NONECONOMIC CRITERIA

The basin scale technologies were also rated on these other noneconomic criterion: land area requirements; operation and maintenance requirements; employment; public health and safety; and local resource availability.

Land Area Requirements

Criterion Weight: 2

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
6	8	10	8	10	10

This criterion measures the land area required to implement a technology. Technologies that require less land for water conveyance, storage and treatment functions are preferable to land intensive technologies according to this criterion. The established rating guidelines for this criteria are as follows: less than 5,000 acres, 10; 5,000 to 10,000 acres, 8; 10,000 to 20,000 acres, 6; 20,000 to 30,000 acres, 4; 30,000 to 50,000 acres, 2; or, greater than 50,000 acres, 1.

The calculated land areas for each alternative were given previously in Table 2-20 of this section. The guidelines indicate the ratings above. However, it should be noted that these ratings are not in direct proportion to the relative land area requirements of each alternative. For example, for both basins, the STA design requires more than 25 times the amount of land when compared to the direct filtration system, but the rating guidelines do not reflect this.

Operation and Maintenance

Criterion Weight: 2

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
7	7	5	7	6	5

This criterion measures the degree of knowledge and effort necessary to properly operate and maintain the conveyance, storage, and treatment facilities required for each alternative. Factors to be considered include total labor requirements, degree of operator training and certification (if any) required, diversity of skills required, specialized machinery or equipment required, degree of regulatory monitoring and reporting required, and sensitivity of treatment performance to a proper operation and maintenance program. The established rating guidelines for this criterion are as follows: the alternative is rated from 1 to 10.

The direct filtration facilities should require what is considered to be a "middle" degree of knowledge and effort to operate and maintain, and they were rated a 5 for both basins. It should be stressed that the direct filtration facilities, as designed, are not considered to be highly complex systems. The other two alternatives being investigated for each basin were rated to reflect the degree of effort and skill required in terms of either greater than or less than this middle alternative. The STA system and the chemical treatment system with a wetland will require very specialized and intense monitoring efforts, and therefore cannot be fully considered to be alternatives that are relatively simple to operate and maintain. The chemical treatment system of Basin S-7 will require a closer monitoring and regulation of chemical dose and effluent quality since there will be no follow-on wetland to provide a polishing step.

Employment

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
1	2	10	1	9	10

Loss of jobs will result from agricultural land being taken out of production for use in the Everglades protection project. This criterion measures the impact on employment of implementing a technology as a function of agricultural land area lost to water conveyance, storage, and treatment facilities. Technologies resulting in low or modest job loss will receive a high rating against this criterion, while alternatives resulting in greater levels of anticipated job loss will receive lower ratings. The established rating guidelines for this criterion are as follows: the alternative is rated from 1 to 10. The higher the rating, the less employment loss the implementation of an alternative creates.

Although there may be a small gain in employment opportunities because of the need for operators, monitoring personnel, and maintenance persons, the number of jobs gained is insignificant compared with the number of jobs lost for all alternatives. Jobs lost consist primarily of farm labor. Secondary job loss may include farm hands, administrative people, supply stores, farm equipment suppliers, etc. The rating of each alternative on this criterion is assumed to be primarily associated with the individual land area which must be taken out of agricultural production. As a starting point, direct filtration was given a rating of 10, since the amount of agricultural land lost due to the construction of a direct filtration system is basically inconsequential when compared with the other alternatives being considered for both basins. The actual land acreage required for each alternative, as was given previously in Table 2-20, were then utilized to proportion the remaining ratings.

Public Health and Safety

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
7	5	6	7	5	6

This criterion measures the potential impact that implementation of a technology will have on the general health and safety of the public. Technologies that could increase exposure of the general public to dangerous chemicals, disease, or unsafe conditions should receive a lower rating against this criterion than alternatives that do not. The established rating guidelines for this criterion are as follows: if the alternative has potential to beneficially impact public health and safety, 8 to 10; if there is no anticipated impact on public health and safety, 7; or, if there is a potential for adverse impact on public health and safety due to the alternative, 1 to 6.

An STA system should not impact public health or safety in any significant way. Because of the exposure to chemicals that the other alternatives require and the associated potential for injury, they were rated in the 1 to 6 range. However, based on prior experience with water and wastewater treatment facilities, the possibility that an accident will occur is remote. Direct filtration was rated more favorably than the alternatives that use sedimentation basins to indicate that direct filtration systems will require less chemical addition than the sedimentation basin alternatives.

Local Resource Availability

Criterion Weight: 1

Basin S-5A			Basin S-7		
STA	Chemical treatment with wetlands	Direct Filtration	STA	Chemical treatment	Direct Filtration
10	5	6	10	5	6

Some technologies require the use of resources or materials that are not available in sufficient quantity in South Florida and must be shipped in from other locations. This criterion measures the extent to which resources outside of South Florida will be needed to construct and operate the required treatment facilities, exclusive of mechanical equipment and its ongoing need for maintenance. The established rating guidelines for this criterion are as follows: if all resources to implement and operate facilities are available in South Florida, 10; if implementation of technology requires periodic importing of resources or importing of small quantities of resources on a continuing basis, 5 to 9; or, if implementation of technology requires importing large quantities of resources on a periodic or continuing basis that are important to the performance of the treatment technologies involved, 1 to 4.

Iron salts, the chemical which will most likely be used for any of the chemical precipitation processes being considered, is not available anywhere in South Florida. However, iron salts can be brought to a treatment facility located in the EAA at a very low price. Alum, another chemical which is being considered for use, is most likely available in sufficient quantity locally. Regardless of which chemical is used, more chemical is required for the systems which use chemical treatment designs than is required for direct filtration system designs. For the STA systems, all vegetation and materials required are currently available in South Florida.

EVALUATION SUMMARY

Table 2-21 presents the totals of the economic and noneconomic scores for the Basin S-5A and Basin S-7 treatment alternatives. Direct filtration systems have the best score in both basins followed by the STA in Basin S-5A and the chemical treatment system in S-7. The difference in the scoring is significant reflecting the overall attractiveness of the direct filtration system especially with respect to economic and performance considerations. In particular, the predictability and reliability of the direct filtration system offers a major contrast to the other two systems.

Table 2-21 Basin Scale Evaluation Summary

	Basin S-5A			Basin S-7		
	STA	Chemical treatment with wetland	Direct filtration	STA	Chemical treatment	Direct filtration
Economic score	155	85	300	155	225	320
Noneconomic score	368	354	482	384	372	508
TOTAL SCORE:	523	439	782	539	597	828

REFERENCES

Anderson, D, 1992. "Introduction and Program Description for Reduction of Phosphorus Concentrations in Agricultural Drainage by Precipitation, Sedimentation, and Drainage."

Bernhardt, H. and H. Schell, 1982. "Energy-Input-Controlled Direct Filtration to Control Progressive Eutrophication." Journal AWWA, 74:5:261.

Bernhardt, H., 1992. Personal communication with Douglas Merrill of Brown and Caldwell.

Boliden Intertrade, 1992. Personal communication with Dick Ward (phone [409] 239-6700) of Boliden Intertrade and Douglas Merrill of Brown and Caldwell, November 1992.

Boller, M., 1984. "Full Scale Exposure with Tertiary Contact Filtration." Wat. Science Technology, Volume 16, Vienna, pages 225-239.

Clasen, J. and H. Bernhardt, 1987. "Chemical Methods of P-elimination in the Tributaries of Reservoirs and Lakes." Schweiz.Z.Hydrol, 49/2.

du Pont, 1992. Personal communication between Rhond Ferenz (phone [800] 441-9603) of the du Pont Company and Douglas Merrill of Brown and Caldwell, November 1992.

General Chemical, 1993. Personal communication between Kenneth Donchue of General Chemical (phone [800] 631-8050) and Douglas Merrill of Brown and Caldwell, January 1993.

Gates, D., C. Loedecke, S. Hermanowicz, and D. Jenkins, 1990. "Mechanism of Chemical Phosphorus Removal in Activated Sludge with Al (III) and Fe (III)." Presented at the ASCE 1990 National Conference on Environmental Engineering, Arlington, VA, July 10, 1990.

Hemphill, B., B. Wiley, and J. Neethin, 1990. "Achieving the Nations Toughest Phosphorus Limit." Presented at the Annual Conference of the California Water Pollution Control Association, Lake Tahoe, California, April 24, 1990.

Kawamura, S., 1987. "Design and Operation of High-Rate Filters." Journal AWWA, 67:10:535.

McCormick, R.F., and P.H. King, 1982. Factors That Affect the use of Direct Filtration in Treating Surface Water." Journal AWWA, 74:5:234.

Montgomery, J.M Consulting Engineers, Inc., 1985. Water Treatment Principles and Design. John Wiley and Sons, New York.

Richwine, R., C. Spani, M. Broeken, and G. Daigger, no date. "Phosphorus Removal at the Rock Creek Facility to Meet a 0.07 mg/L Total Phosphorus Standard." Source of paper not available.

Stumm, W. and J. Morgan, 1970. Aquatic Chemistry. Wiley Intersclone, New York, New York, page 522.

Wagner, E.G., and H.E. Hudson, Jr., 1982. "Low-Dosage High-Rate Direct Filtration." Journal AWWA, 74:5:234.22.

CHAPTER 3

FARM-SCALE TREATMENT ALTERNATIVES

In Chapter 3, phosphorus removal alternatives for two types of "model" farms, a 6,400-acre sugarcane farm and a 1,280-acre vegetable farm are evaluated. Sugarcane and vegetable production represents about 92 percent of the land area within the Everglades Agricultural Area (EAA). According to a January 1993 Technical Memorandum by Burns & McDonnell, sugarcane production accounts for approximately 461,000 acres, or about 89 percent, of the land area in the EAA. Vegetable production accounts for approximately 25,000 acres, or about 5 percent, of the total EAA land area. Farms of other types and sizes were not considered in this analysis.

Direct agricultural runoff from farms represents about 77 percent of the total flow into the EAA (based on data over the period of record from 1979 through 1988). The other source is Lake Okeechobee, which accounts for about 23 percent (Burns & McDonnell, 1992) of total flow into the EAA. Waters from the EAA flow into the Water Conservation Areas (WCAs) to the south and subsequently into the Everglades. It is currently estimated that direct agricultural runoff from farms accounts for approximately 86 percent of the current total annual average phosphorus load discharged as EAA runoff to the WCAs (Burns & McDonnell, 1992).

Analysis of phosphorus removal technologies at the farm level provides: (1) a cost comparison with phosphorus removal technologies at the basin scales, (2) an evaluation of potential for combining farm-scale phosphorus removal alternatives at the point source and basin-scale for more cost-effective reduction of phosphorus leaving the EAA, and (3) a clearer understanding of the technical and financial feasibility of instituting farm-scale phosphorus removal technologies for the direct treatment of agricultural runoff.

Table 3-1 presents the three top-rated phosphorus removal technologies which were evaluated for the farm scale. This list differs somewhat from the list presented in the Phase I Evaluation of Alternative Treatment Technologies (Brown and Caldwell, 1992). Specifically, it was determined that chemical treatment combined with a follow-on wetland was not a cost-effective alternative. Therefore, it was decided to analyze chemical treatment with sedimentation basins as an independent alternative as well as in-canal chemical treatment where existing drainage canals are converted into chemical treatment facilities.

Table 3-1 Farm-Scale Phosphorus Removal Alternatives

Model sugarcane farm	Model vegetable farm
Farm stormwater treatment area (FTA)	FTA
Chemical treatment with sedimentation basins	Chemical treatment with sedimentation basins
In-canal chemical treatment and sedimentation	In-canal chemical treatment and sedimentation

DEVELOPMENT OF DESIGN DATA

Design data was developed by defining the model farms, estimating flows and pollutant loadings, and estimating the size of the treatment systems required.

Model Farms

Through discussions with the District, it was decided that a 6,400-acre area (10 square miles) approximated a "model" sugarcane farm. Similarly, 1,280 acres (2 square miles) was chosen to approximate a "model" vegetable farm. In many instances, parts of sugarcane farms are periodically rotated off of sugarcane production and into vegetable production. A 1,280-acre vegetable farm represents those parts of sugarcane farms which have been converted to vegetable production as well as smaller vegetable farms within the EAA.

Farm-Scale Runoff Water Characteristics

Historic phosphorus loads associated with drainage from various land uses in the EAA have been reported by several researchers. Average phosphorus concentrations from sugarcane and vegetable farms are assumed to be 0.12 and 0.34 mg/l, respectively (IFAS, 1991). These phosphorus concentrations represent the average for runoff water from each model farm assuming standard farming practices. In this analysis, these concentrations are used with the understanding that additional information may alter future runoff data due to ongoing research and/or changes in standard farming practices within the EAA.

Farm-scale flows were developed from historical rainfall data from the period of record from 1980 through 1988 (incomplete 1979 rainfall data were omitted). In evaluating the intensity of rainfall on the model farms, rainfall data were used as input to a modified water budget model developed by Melaika and Bottcher (Melaika and Bottcher, 1988). The model was subsequently modified by Mock, Roos & Associates. Results of water budgeting modeling are reported in the concurrent on-farm best management practices (BMP) study performed by Brown and Caldwell as Amendment No. 3 to Contract C-3051.

The modeling was performed using daily rainfall data with estimates of daily evapotranspiration (ET), daily basin-wide irrigation demands, and drainage volumes over the 9-year period record. The model was calibrated against basin-wide irrigation demands for (Basin S-5A) as computed by Burns & McDonnell (Burns & McDonnell, Technical Memorandum, September 1992) and District data for discharges from the Basin S-5A Pump Station for that same period of record. Daily, monthly, and annual run-off totals were estimated by modeling these historical data.

Agricultural runoff water total suspended solids (TSS) constitute a significant portion of the sludge produced during treatment. Therefore, the TSS concentrations from farm runoff must be estimated. Statistical analyses were performed on TSS information in the District's water quality data base for both Basin S-5A and Basin S-7. These analyses indicated that the 50th percentile TSS concentrations were 19 and 6 mg/l for Basin S-5A and Basin S-7, respectively. In lieu of additional data related to TSS and EAA water quality, the mean of these two-basin scale TSS concentrations (13 mg/l) was assumed for farm-scale runoff TSS concentration.

Sizing Treatment Plants

Chemical treatment facilities were sized following the same general procedures described in Chapter 2 for sizing basin-scale plants. Farm-scale phosphorus loads were estimated for the period of record from runoff and phosphorus concentration data. Estimates of phosphorus residuals in treated waters from farm-scale chemical treatment units were made (see Table 3-2).[1] Next, simulations were made of plants, having varying flow capacity and phosphorus removal capability, treating part of the flow while bypassing the remaining flow. Effluent phosphorus loadings in the recombined waters were then expressed as a percentage of the phosphorus load in the full flow, with the value of 100 minus that percentage representing the overall phosphorus removal.

Table 3-2 Estimates of Phosphorus Residuals in Effluents From Farm-Scale Treatment Units That Use Chemical Precipitants

Item	Model sugarcane farm		Model vegetable farm	
	Chemical treatment, sedimentation basins	In-canal chemical treatment	Chemical treatment, sedimentation basins	In-canal chemical treatment
Influent phosphorus, mg/l	0.120	0.120	0.340	0.340
Phosphorus, mg/l (after reaction but before solids separation)				
Dissolved phosphorus	0.010	0.010	0.010	0.010
Particulate phosphorus	0.110	0.110	0.330	0.330
Subtotal, influent phosphorus	0.120	0.120	0.340	0.340
Percent particulate phosphorus removed	80	70	70	70
Phosphorus, mg/l (after solids separation)				
Dissolved phosphorus	0.010	0.010	0.010	0.010
Particulate phosphorus	0.022	0.033	0.066	0.099
Subtotal, phosphorus residual	0.032	0.043	0.076	0.109

1 Dissolved phosphorus residuals of 0.010 mg/l were assumed for farm-scale operation. These residuals are slightly higher than dissolved phosphorus residuals selected for basin-scale operations (0.005 mg/l), reflecting expected lower operator skills and less attention on farm-scale treatment systems.

The result is a series of curves depicting overall percent phosphorus removal versus treatment plant capacity for different concentrations of treatment plant effluent phosphorus. Figures 3-1 and 3-2 present phosphorus removal curves specifically generated for the model 6,400-acre sugarcane farm and the model 1,280-acre vegetable farm, respectively.

The treatment goal for phosphorus removal for sugarcane farm alternatives is the same as for basin-scale alternatives (effluent phosphorus concentration of 0.05 mg/l). The treatment goal for vegetable farm alternatives is 0.10 mg/l phosphorus, except for the in-canal chemical treatment alternative. This latter system can only reduce phosphorus to about 0.11 mg/l, even when treating all the flow. Therefore its treatment goal is 0.11 mg/l, and it must treat <u>all</u> the flow. The vegetable farm alternatives are allowed the higher treatment goals simply because they cannot achieve the normal 0.05 mg/l goal, given the high untreated water phosphorus concentration of 0.34 mg/l (see Table 3-2). Note that even though the treated effluent phosphorus concentration is relatively high (0.10 to 0.11 mg/l), the percentage phosphorus removal is still significant (approximately 70 percent).

CHEMICAL TREATMENT

Chemical treatment systems use the same process train as basin-scale chemical treatment alternatives, namely: initial pumping, chemical addition, rapid mixing, flocculation, sedimentation in earthen basins, solids thickening, and solids disposal on dedicated land. Mechanical sludge dewatering, followed by landfilling of the dewatered sludge, is a more expensive alternative to dedicated land disposal of thickened sludge, but it eliminates environmental concerns. Our current analysis assumes the dedicated land disposal option will be implemented.

Design parameters for farm-scale chemical alternatives are the same as for the basin-scale alternatives. Chapter 2 provides a detailed description of the chemical treatment process. Figure 3-3 shows a schematic flow diagram for chemical treatment alternatives for farm-scale flows. Table 3-3 provides the basis of design for farm-scale chemical treatment facilities.

Capital costs for farm-scale chemical treatment systems are calculated with the same assumptions and methods used to estimate basin-scale capital costs presented in Chapter 2. Chemical treatment capital costs are driven primarily by flocculation, sedimentation and electrical/instrumentation costs. Capital costs are estimated at $4.4 million and $1.9 million for sugarcane farm and vegetable farm treatment facilities, respectively.

Annual O&M costs are estimated at $0.23 million for sugarcane farms and $0.14 million for vegetable farms. O&M estimates were calculated using the same assumptions as O&M calculations presented in Chapter 2.

The present value cost of the farm-scale chemical treatment alternatives for model sugarcane farms and model vegetable farms are $6.6 million and $3.3 million, respectively, based on a 20-year project and a 8 percent discount rate.

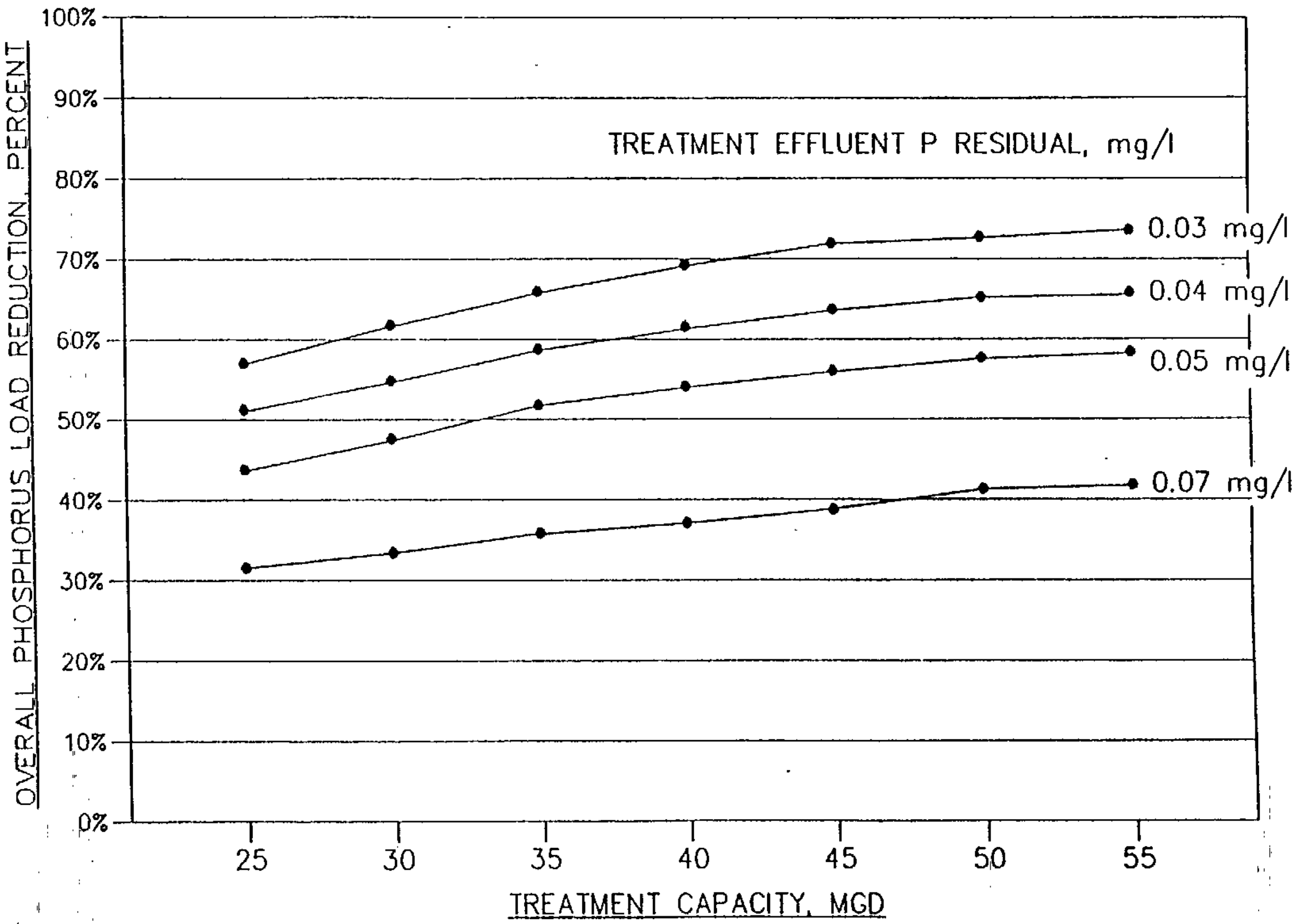

FIGURE 3-1.
RELATIONSHIP OF TREATMENT CAPACITY AND EFFLUENT P CONCENTRATION TO REDUCTION IN P LOAD ON MODEL SUGARCANE FARMS

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E:/7138/FIG3-1

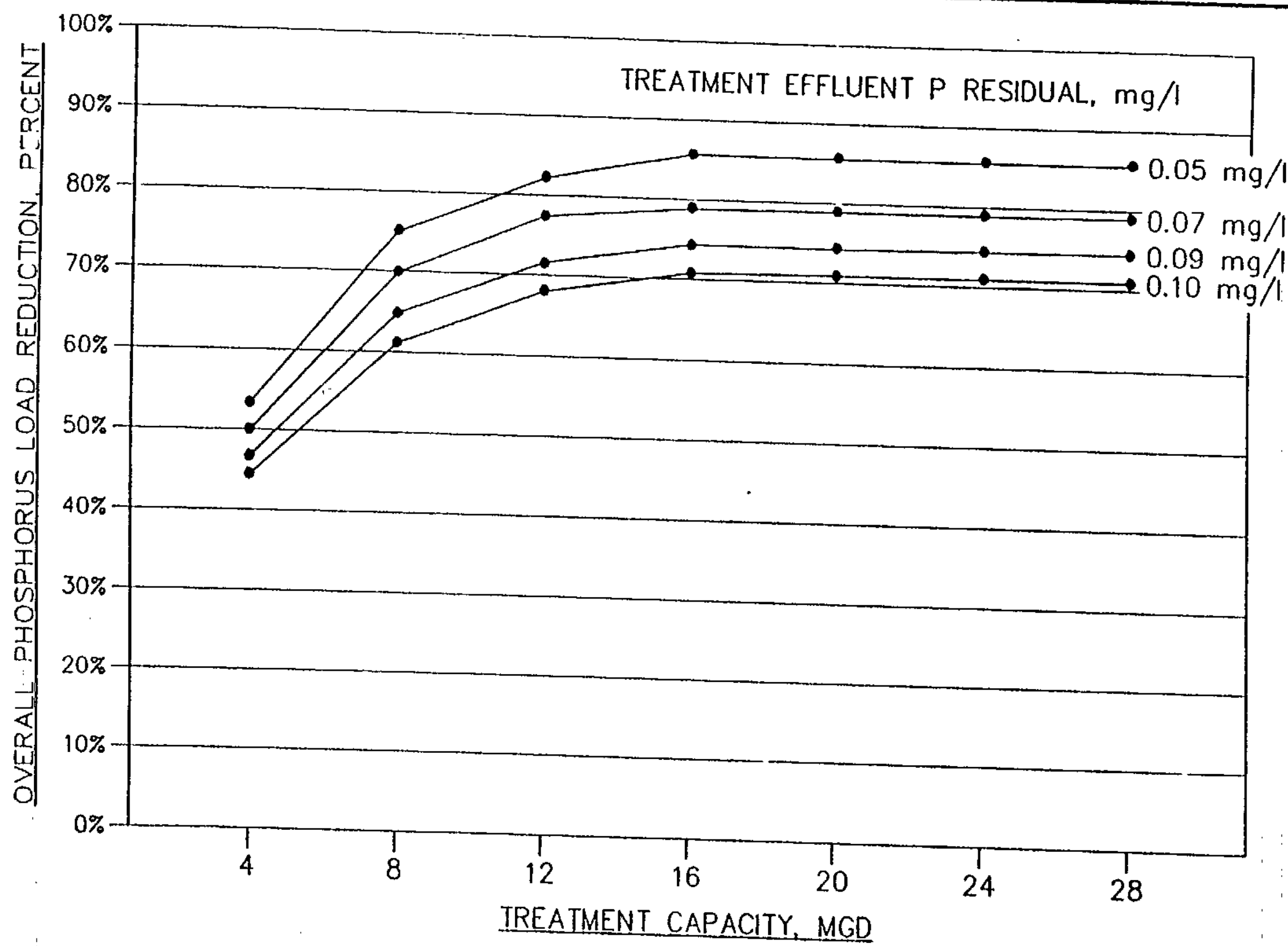

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FIGURE 3-2.
RELATIONSHIP OF TREATMENT CAPACITY AND EFFLUENT P CONCENTRATION TO REDUCTION IN P LOAD ON MODEL VEGETABLE FARMS

E:/7138/FIG3-2

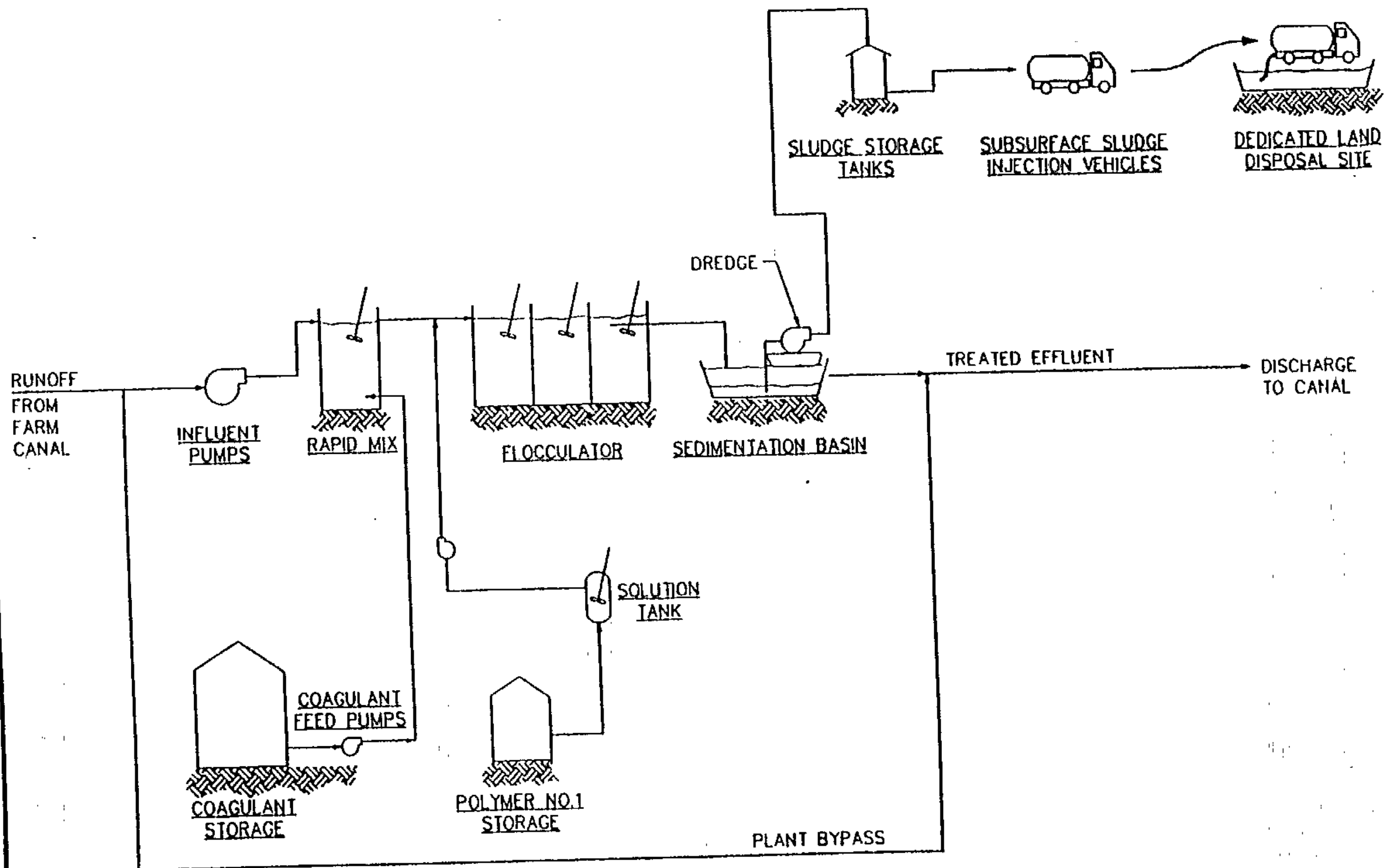

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FIGURE 3-3.
SCHEMATIC FLOW DIAGRAM
FARM-SCALE CHEMICAL
TREATMENT SYSTEMS

E:/7138/FIGES-3

Table 3-3 Basis of Design for Farm-Scale Chemical Treatment

Item	Model sugarcane farm	Model vegetable farm
Area, acres	6,400	1,280
Flow, million gals[a]		
Average annual	3,716	1,368
Maximum annual	5,474	1,838
Average phosphorus, mg/l[b]	0.12	0.34
Average, TSS, mg/l[c]	13	13
Plant data		
Percent of days on-line	52	52
Flow, mgd		
Maximum	27	9
Minimum	0	0
Average		
All days	8.1	3.4
When operating	15.6	6.5
Maximum year		
Average all days	11.7	4.1
When operating	22.4	7.8
Influent pumps		
Peak plant flow, mgd	27	9
Number of pumps, in parallel	3	2
Capacity each, gpm	10,000	7,500
Rapid mix tanks		
Number, in parallel	1	1
Volume, each, gal	625	210
Detention time at peak plant flow, sec	2	2
Mixer	Turbine	Turbine
Velocity gradient, sec^{-1}	750	750
Power input per tank, hp	3	1
Material of construction	Concrete	Concrete
Flocculators		
Number, in parallel	1	1
Stages per flocculator	3	3
Volume per stage, gal	187,000	62,500
Detention time per stage at peak flow, mins	10	10
Mixer	Horizontal paddle	Horizontal paddle
Velocity gradient, sec^{-1}		
Minimum	20	20
Maximum	90	90
Power input per stage, hp		
Minimum	0.5	4
Maximum	11	0.2
Material of construction	Concrete	Concrete

Table 3-3 Basis of Design for Farm-Scale Chemical Treatment (continued)

Item	Model sugarcane farm	Model vegetable farm
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33% $FeCl_3$	Liquid, 33% $FeCl_3$
Dose, as Fe, mg/l		
Average	10	10
Maximum	15	15
Pumps		
Number (1 spare)	2	2
Capacity, each, gpm	2	1
Storage tank		
Volume, gal	36,000	12,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2
Polymer		
Form	Liquid	Liquid
Dose, mg/l		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	2	2
Capacity, each, gph	7	4
Solution tank volume, gal	275	100
Storage tank		
Volume, gal	80	30
Storage at peak feed rates, wks	2	2
Sedimentation basins		
Number in parallel	1	1
Depth, ft	14	14
Width, each, ft	208	70
Length, each, ft	360	360
Forward displacement velocity at peak flow, ft/min	1.0	1.0
Overflow rate at peak flow, gpd/ft^2	360	360
Detention time, hrs	6	6
Weir loading rate, gpm/ft	15	15
Dredges		
Number	1	1
Capacity, gpm	200	100
Material of construction	Earth	Earth

Table 3-3 Basis of Design for Farm-Scale Chemical Treatment (continued)

Item	Model sugarcane farm	Model vegetable farm
Dedicated land disposal		
Application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	1	1
Area per section, acres	23	8
Number of nurse tanks	2	2
Volume each nurse tank, gal	600	600
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	1	1
Spreading capacity each, gal/day	25,000	10,000

[a] Compiled from daily rainfall data from years 1980 to 1988, inclusive.
[b] IFAS, Final Report, Area 3, Volume II, January 1991.
[c] Mean of basin scale TSS calculated from District water quality data base.

IN-CANAL CHEMICAL TREATMENT

Existing drainage canals on farms are designed to control both surface and subsurface water levels and for water conveyance. Because their original design was for these purposes alone, modifications for use as chemical treatment facilities are necessary. Current sizes and volumes of drainage canals vary depending on location. Brown and Caldwell's on-farm best management practices (BMP) study has revealed that more advanced BMPs may include on-farm water table management. Effective water table management would include expanding and modifying farm drainage canals to increase the hydraulic capacity. Thus, drainage canal modifications for water table management could be linked to an in-canal chemical treatment approach. In addition, increased water storage may be recommended as a BMP. It may be possible to combine farm- scale water storage approaches with a chemical treatment approach within water storage basins.

Description

Figure 3-4 shows the schematic flow diagram for in-canal chemical treatment. In-canal phosphorus removal treatment facilities are configured to be below the existing ground surface. They are constructed by modifying the drainage systems that exist on each of the sugarcane and vegetable farms in the EAA. By locating treatment plants within existing drainage canals, in-canal chemical treatment: (1) consumes less acreage of productive farmland, and (2) saves capital construction costs. The in-canal systems are designed to be similar to the aboveground chemical treatment systems, but less expensive by virtue of using already existing facilities and low-cost earthen construction. Table 3-4 provides the basis of design for in-canal chemical treatment systems.

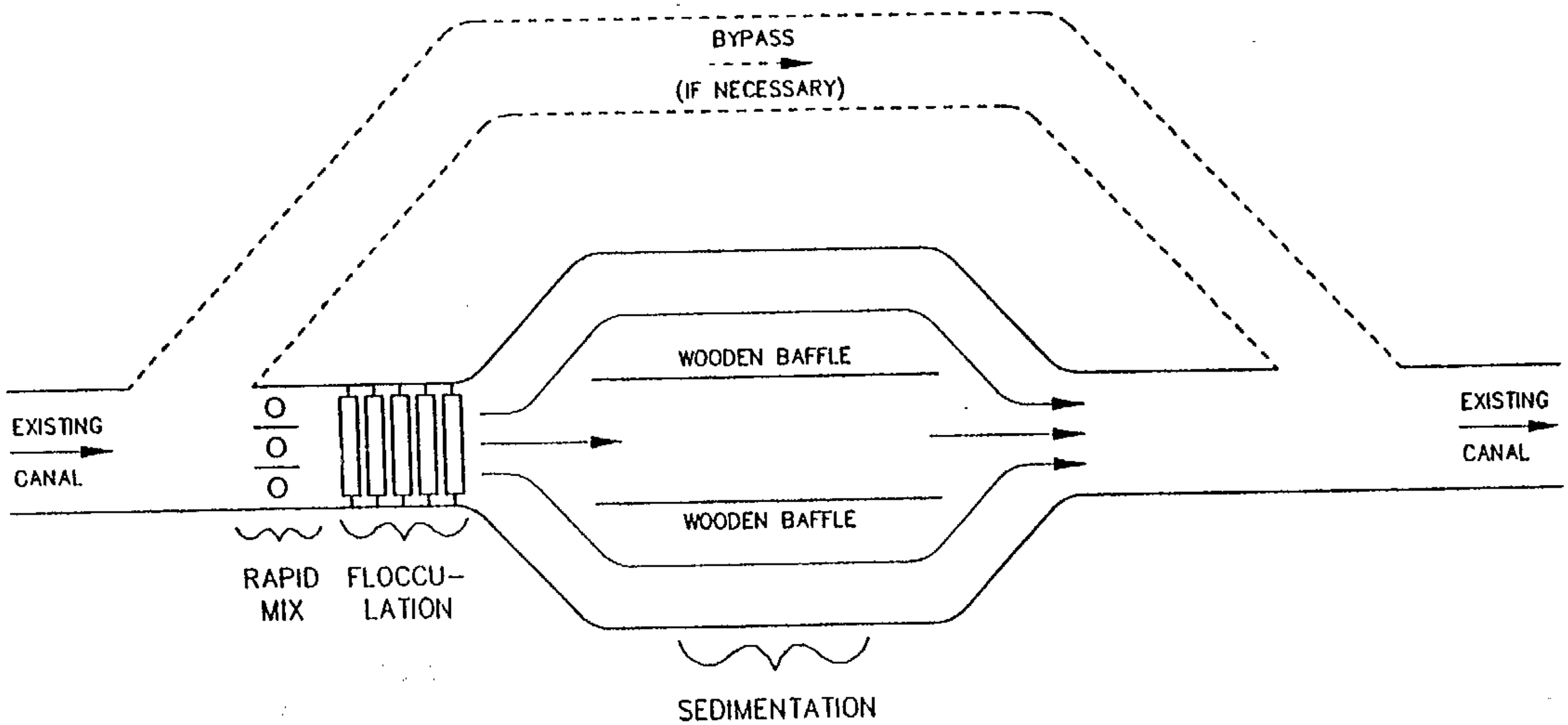

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FIGURE 3-4.
CONCEPTUAL DIAGRAM OF
FARM-SCALE IN-CANAL
CHEMICAL TREATMENT

E:/7138/FIG3-4

Table 3-4 Basis of Design for Farm-Scale In-Canal Chemical Treatment

Item	Model sugarcane farm	Model vegetable farm
Area, acres	6,400	1,280
Flow, million gals[a]		
Average annual	3,716	1,368
Maximum annual	5,474	1,838
Average phosphorus, mg/l[b]	0.12	0.34
Average, TSS, mg/l[c]	13	13
Plant data		
Percent of days on-line	52	52
Flow, mgd		
Maximum	34	16
Minimum	0	7.1
Average		
All days	9.2	3.7
When operating	17.2	7.1
Maximum year		
Average all days	13.4	5.0
When operating	25.7	9.7
Influent pumps		
Peak plant flow, mgd	34	16
Number of pumps, in parallel	3	2
Capacity each, gpm	10,000	10,000
Rapid mix tanks		
Canal width, ft	30	30
Water depth, ft	10	10
Length of rapid mix zone, ft	5	2.5
Detention time at peak flow, secs	30	30
Number of mixers	3	3
Velocity gradient, sec^{-1}	250	250
Flocculators		
Canal width, ft	30	30
Water depth, ft	10	10
Length of flocculation zone, ft	315	148
Detention time at peak flow, min	30	30
Number of flocculators	16	8
Velocity gradient, sec^{-1}		
Minimum	20	20
Maximum	90	90

Table 3-4 Basis of Design for Farm-Scale In-Canal Chemical Treatment

Item	Model sugarcane farm	Model vegetable farm
Chemical addition systems		
$FeCl_3$		
Form	Liquid, 33% $FeCl_3$	Liquid, 33% $FeCl_3$
Dose, as Fe, mg/l		
Average	10	10
Maximum	15	15
Pumps		
Number (1 spare)	2	2
Capacity, each, gpm	3	1.5
Storage tank		
Volume, gal	61,000	31,000
Liner	Rubber	Rubber
Storage time at peak feed rates, wks	2	2
Polymer		
Form	Liquid	Liquid
Dose, mg/l		
Average	0.1	0.1
Maximum	0.2	0.2
Pumps		
Number (1 spare)	2	2
Capacity, each, gph	10	7
Solution tank volume, gal	350	200
Storage tank		
Volume, gal	100	50
Storage at peak feed rates, wks	2	2
Sedimentation basins		
Number	1	1
Width, ft	263	124
Length, ft	360	360
Depth, ft	15	14
Maximum forward flow at peak flow, ft/min	1	1
Detention time at peak flow, hours	6	6
Overflow rate at peak flow, gpd/ft^2	360	360
Dredges		
Number	1	1
Capacity, gpm	100	40
Dedicated land disposal		
Application rate, tons dry solids per acre per year	28.4	28.4
Number of sections	1	1
Area per section, acres	35	14
Number of nurse tanks	2	2
Volume each nurse tank, gal	600	600
Spreading season, mos	6	6
Subsurface sludge injection vehicles		
Number	1	1
Spreading capacity each, gal/day	40,000	15,000

[a] Compiled from daily rainfall data from years 1980-1988, inclusive.
[b] IFAS, Final Report, Area 3, Volume II, January 1991.
[c] Mean of basin scale TSS calculated from District water quality data base.

If all the flow is to be treated, the treatment systems are installed entirely in a modified existing canal. If some of the flow is to be bypassed, the bypassed flow is conveyed around the treatment unit in a parallel channel. It is assumed that the natural head in the canal is sufficient to drive both treated and bypassed flows, i.e., booster pumping is not provided.

Rapid mixing is provided by turbine mixers suspended from a bridge above the canal. The mixers are separated and compartmentalized by vertical wooden baffles mounted parallel to flow. The upstream and downstream ends of the compartment are open so as not to restrict flow. The nominal liquid detention time in the rapid mix tank is on the order of 30 seconds.

Flocculation is provided by a series of reel-type paddles located downstream of the rapid-mix section. The paddles are mounted perpendicular to flow and span the width of the canal. Canal walls are cut vertically in the flocculation sector to prevent obstruction of the rotation of the paddles. Paddle speed is reduced in the direction of flow to provide tapered flocculation. Nominal liquid detention time in the flocculation section is 30 minutes at peak flow.

Solids settling occurs in an expanded section located immediately downstream of the flocculators. The sludge accumulates in the bottom of the sedimentation section and thickens. During dry months the accumulated solids are removed from the bottom of the sedimentation section by a floating dredge for subsequent disposal on dedicated land. The sedimentation section is designed to limit average liquid forward velocity (scouring velocity) to 1 ft/min and provide a 6-hour detention time at peak flow. The sedimentation section is deep enough to provide a water depth of 12 feet plus space to accumulate 6 months of sludge production.

Thickened sludge is deposited on dedicated land during dry months when the sludge can be dried by evaporation. The sludge is applied beneath the surface by tank trucks using specially designed plows. See Chapter 2 for a detailed description of disposal methods and site sizing calculations.

It has been assumed that phosphorus residuals of 0.076 and 0.109 mg/l can be obtained with in-canal treatment of sugarcane farm and vegetable farm drainage, respectively (see Table 3-2). It is not entirely clear that these residuals can be obtained in units that lack flow distribution features such as weirs and flow distribution channels. These features have been omitted to minimize headloss. Also, canal construction limits some design parameters. For example, it is not possible to provide the short detention time desired for rapid mixing without constricting the canal and severely reducing its flow capacity. Effectiveness of in-canal treatment should be demonstrated experimentally in prototype units if the alternative is considered further.

There are also questions concerning compliance and enforcement of the farm-scale chemical treatment approach. Chemical treatment of farm-scale flows is currently not a formal component of the Surface Water Improvement and Management (SWIM) plan. Questions concerning enforcement and compliance would need to be addressed directly in the upcoming plan formulation stage.

<u>Costs</u>

As discussed above, capital costs of in-canal systems would be modified as additional information and data are gathered from an experimental prototype. However, it is currently anticipated that in-canal chemical treatment facilities would be less expensive to build than aboveground chemical treatment systems. Capital costs are estimated to be \$5.7 million and \$3.2 million for sugarcane farms and vegetable farms, respectively.

Annual sugarcane farm in-canal treatment O&M costs are estimated at \$0.24 million and vegetable farm in-canal O&M costs are estimated to be \$0.14 million.

Total present worth costs over the 20-year design life of the in-canal chemical treatment facilities are estimated to be \$8.1 million and \$4.6 million for the model 6,400-acre sugarcane farms and model 1,280-acre vegetable farms, respectively.

FARM TREATMENT AREAS

FTAs are small-scale STAs. The same phosphorus removal mechanisms are at work, and they are sized using the same design parameters. FTAs consist of pump stations, flow way and polishing cells, levees, and control structures.

The FTA active area is calculated with Equation 3-1:

$$A = \frac{P_1 - Q_{i}C_o}{0.5k\ (C_i + C_o) - 1.23\ C_p - 0.17\ C_o} \qquad (3\text{-}1)$$

where:

A	=	Active area, m^2
P_1	=	Annual influent phosphorus loading, gms
Q_i	=	Annual influent flow, m^3
K	=	First order settling rate constant m/yr
C_i	=	Average phosphorus concentration in FTA influent, mg/l
C_o	=	Average phosphorus concentration in FTA effluent, mg/l
C_p	=	Average phosphorus concentration in rainfall, assumed to be 0.03 mg/l.

The District's draft FTA report (SFWMD, 1992) provides the basis for Equation 3-1. A value of 8.0 m/yr was used in the calculations, to be consistent with the approach used by the District in sizing FTAs. C_i values of 0.12 and 0.34 mg/l phosphorus were used for sugarcane and vegetable FTAs, respectively. The corresponding C_o values were 0.05 and 0.10 mg/l phosphorus.

The sugarcane FTA active area is 383 acres, and its total acreage is 460 acres. The vegetable FTA active area is 180 acres, and its total acreage is 230 acres.

Capital costs are estimated to be \$5.0 million and \$2.8 million for sugarcane and vegetable FTAs, respectively. Annual O&M costs for sugarcane and vegetable FTAs are estimated to be \$0.16 million and \$0.08 million, respectively. Present worth costs for sugarcane and vegetable FTAs are estimated to be \$6.6 million and \$3.6 million, respectively.

PRESENT WORTH COSTS FOR FARM-SCALE TREATMENT ALTERNATIVES

Table 3-5 summarizes present worth costs of the farm-scale alternatives. The sugarcane farm chemical treatment and FTA alternatives have approximately the same present worth. The in-canal chemical treatment system is more costly than the chemical treatment alternative because it must treat a larger part of the flow to satisfy phosphorus removal requirements. It must do so because it is not capable of reducing the phosphorus concentration to as low a value as the chemical treatment alternative.

Table 3-5 Present Worth of Farm-Scale Alternatives

Item	Cost, million dollars[a]			Cost, dollars per pound of phosphorus removed
	Capital	O&M	Present worth[b]	
Sugarcane farm				
Chemical treatment	4.4	0.23	6.6	162[c]
In-canal chemical treatment	5.7	0.24	8.1	187[c]
FTA	5.0	0.16	6.6	152[c]
Vegetable farm				
Chemical treatment	1.9	0.14	3.3	60[d]
In-canal chemical treatment	3.2	0.14	4.6	84[d]
FTA	2.8	0.08	3.6	68[e]

a Costs in 1992 dollars.
b Present worth = capital cost + f (O&M cost) where f = 9.8181 based upon 20-year life and a discount rate of 8 percent.
c 43,400 pounds of phosphorus removed over 20 years.
d 54,800 pounds of phosphorus removed over 20 years.
e 52,500 pounds of phosphorus removed over 20 years.

The same general situation occurs on the vegetable farms. The chemical treatment and FTA alternatives have approximately equal present worths; the in-canal chemical treatment system is more costly. Table 3-5 also summarizes the cost per pound of phosphorus removal. The cost per pound phosphorus removed is equal to the present worth distributed over the pounds of phosphorus removed during the 20-year project life. The cost per pound of phosphorus removed is lowest with the vegetable farm systems, mainly because their phosphorus feedwater concentrations are relatively high compared with the feedwaters to the sugarcane farm systems. Treatment of vegetable farm runoff will not have a major impact on overall phosphorus removals because vegetable farms account for only a small portion of the P in EAA runoff.

REFERENCES

Brown and Caldwell. Everglades Protection Project--Phase I Evaluation of Alternative Treatment Technologies. Draft Report. Prepared for the South Florida Water Management District. October 2, 1992.

Burns & McDonnell. Everglades Protection Project, Conceptual Design Stormwater Treatment Areas. March 31, 1992.

University of Florida IFAS. Biogeochemical Behavior and Transport of Phosphorus in the Lake Okeechobee Basin. Final Report, Area 3, Volume II. January 1991.

Melaika, N.F. and A.B. Bottcher. "Irrigation and Drainage Management Model for Florida's Everglades Agricultural Area." Transactions of the American Society of Agricultural Engineers. Vol. 31, No. 4. 1988.

U.S. Environmental Protection Agency Office of Research and Development. Phosphorus Removal Design Manual. Center for Environmental Research Information. Cincinnati, Ohio. September 1987.

Table A-1 Comparison of Direct Filtration Influent and Treated Water Composition and Florida Water Quality Standards

Parameter[a]	EAA Discharge		Expected Changes Caused By Treatment	Treated Effluent		Blended Effluent		FDER Water Quality Standards		Comment
	S-5A	S-7		S-5A	S-7	S-5A	S-7	Class I	Class III	
Alkalinity, as $CaCO_3$	244	289	-11, -18	229	271	232	280	>20	>20	
Ammonia (un-ionized), μg/L	<3	1	—	<3	1	<3	1	20	20	
Barium	—	—	—	—	—	—	—	1	—	
Bacteria	—	—	Significant reduction	—	—	—	—	1,000 per 100 ml	200 per 100 ml	
Beryllium	—	—	Some reduction					1.1	1.1	
Biological integrity	—	—	—	—	—	—	—	[b]	[b]	
Bromine and bromates	—	--	—	—	—	—	—	0.1, 100	0.1, 100	
Cadmium, μg/L	1.46	1.17	-0.4, -0.7	1.1	0.8	1.2	1.0	1.2	1.2	Treatment may reduce Cd to satisfy water quality standards.
Chlorine, total residual	—	—	—	—	—	—	—	0.01	0.01	
Chloride	188	145	+11[c]	199[c]	156[c]	197	151	250	—	
Copper, μg/L	15	10	-7	8	2	10	6	30	300	
Cyanide	—	—	—	—	—	—	—	—	—	
Total dissolved solids[d]	791	677	+11[c]	802	687	800	682	500 average 1,000 maximum		Standard for total dissolved solids already exceeded in untreated water.
Fluoride	—	—	Minor reduction	—	—	—	—	1.5	—	
Iron	0.3	0.16	Minor reduction	0.10	0.10	0.15	0.13	0.3	1.0	80 to 90 percent of EAA Fe is particulate.
Lead, μg/L	2.1	1.3	Minor reduction	2.0	1.0	2.0	1.1	30	30	Lead standard may be reduced in the future.
Mercury, μg/L	—	—	Minor reduction	—	—			0.2	0.2	

CHAPTER 4

POINT SOURCE TREATMENT ALTERNATIVES

There are three types of point sources of wastewater in the Everglades Agricultural Area (EAA): (1) sugar mills, (2) package treatment plants for labor camps and small villages, and (3) municipal wastewater treatment plants. In this chapter, these point sources are described and potential wastewater treatment alternatives for each point source are evaluated.

SUGAR MILLS

This section presents a description of the current sugar milling processes and waste streams, a summary of current waste stream treatment practices, an assessment of treatment practices proposed by the sugar industry, and an assessment of other feasible treatment alternatives.

Milling Processes

Sugarcane is processed in a similar fashion at each of the seven sugar mills in the EAA. In general, the milling process from sugarcane to raw sugar can be described by the following steps:

1. Cane unloading
2. Conveyance of cane through levelers and knives
3. Crushing of cane to produce raw juice
4. Weighing and liming of juice
5. Heating and clarification of juice
6. Evaporation of juice to produce syrup
7. Filtration of syrup to remove impurities
8. Crystallization to form raw sugar
9. Shipping or storage of raw sugar in warehouses.

Each facility has a steam plant and an associated electric plant. The steam plants usually use crushed cane (bagasse) as all, or a portion, of the steam plant fuel. The stack gas from the steam plant is scrubbed to remove particulates in the discharge to the atmosphere.

Waste Streams

Sugar mill waste streams vary depending on the equipment and physical plant design. In general, waste streams can be summarized as follows:

- Equipment bearing cooling water and floor washings from the crushing operation
- Boiler room (i.e., steam generation) wastewater

- Bottom ash
- Scrubber blowdown
- Filtrate (cachaza) from the syrup filtration process
- Condensate and floor washings from the evaporation, filtration, and crystallization processes
- Stormwater.

The waste streams tend to have relatively high phosphorus concentrations. Combined liquid streams have phosphorus concentrations in the 20 to 30 mg/l range, while sludges may have phosphorus concentrations as high as 500 to 600 mg/l.

Current Treatment Practices

The current treatment practices for sugar mill waste streams vary between mills, although most mills use anaerobic ponds for storage, treatment, and percolation of wastewaters and sludges. Separate ponds are often provided for wastewaters and sludges. Most mills use passive anaerobic percolation ponds with no surface water discharge; however, one mill provides aerobic ponds after the anaerobic ponds and internal recycle pumping. In a few cases, wastewaters are directly discharged to canals which are connected to the main drainage system for the EAA. A summary of the treatment and disposal methods used for the waste streams at each of the mill sites is provided in Table 4-1.

Some removal of phosphorus from the sugar mill waste streams is accomplished through biological processes, removal of sludges in the ponds, and soil removal mechanisms. Phosphorus in the waste streams entering the ponds occurs in two forms, soluble and particulate phosphorus. Particulate phosphorus is associated with the solids in the waste stream. Biological processes in the ponds convert a portion of the soluble phosphorus to particulate phosphorus in the form of biomass. Most of the phosphorus associated with the solids in the wastewater or sludge is then removed by settling in the ponds or filtration in the soils at the bottom of the ponds. Additional phosphorus is removed by sorption and precipitation in the soil. A portion of the phosphorus load remains as the water seeps into the surrounding groundwater.

Pond treatment of mill waste streams results in accumulation of sludges. The procedures for managing sludges vary from mill to mill. Some mills remove sludges from the ponds by periodic dredging. The dredged sludges usually are applied to agricultural lands. Some mills, including U.S. Sugar Corporation's Bryant and Clewiston mills, periodically dredge dried sludge near the perimeter of the ponds and use this material to increase the height of the pond retaining berms, thus providing additional future storage.

Table 4-1 Summary of Sugar Mill Waste Stream Treatment and Disposal Methods

Sugar mill site	Mill tandems		Boiler room wastewater	Scrubber tank overflow	Excess blowdown	Fabrication department			Stormwater	Sanitary waste
	Mill bearings	Floor washings				Mud slurry (mud sluicing and filtrate)	Floor washings	Condensate		
Clewiston	WW	WW	WW	WW	WW	S	WW	WW	WW	NK
Osceola Farms	S	S	IC	S	S	S	S	IC	IC	S
Okeejanta	IC	IC	IC	IC	IC	S	S	NK	NK	NK
Bryant	WW	WW	WW	S	WW	S	WW	WW	WW	NK
Atlantic	IC OD	IC OD	IC OD	S	S	S	IC OD	IC OD	IC	IC
Talisman	WW	WW	WW	WW	AP	AP/S	WW	WW	NK	WW
Sugar Cane Growers Coop	WW	WW	S	WW	WW	S	WW	S	NK	NK

Definitions:

WW = Wastewater percolation pond.
S = Sludge percolation/drying pond.
AP = Ash pond.
IC = Irrigation canal--no off-site discharge.
IC OD = Irrigation canal--off-site discharge.
NK = Not known.

Proposed Treatment Practices

In a presentation to the District Governing Board in April 1992, the Florida Sugar Cane League stated that the historic waste stream treatment practices at the sugar mill sites have resulted in the contribution of phosphorus to the EAA canals. U.S. Sugar Corporation has proposed modifications to reduce phosphorus loading to the canals. These modifications were in progress during Brown and Caldwell's visit to the mills in November 1992.

At U.S. Sugar Corporation's Bryant and Clewiston mills, the canals surrounding the mill sites are being modified in an attempt to create a hydrologically isolated island of land around the sugar mills and the waste ponds. To achieve this, U.S. Sugar Corporation proposes to implement large-scale reuse of water, install soil plugs in discharge canals, and remove discharge pumps from the mill drainage basin.

The water levels in the canals surrounding the sugar mills and the waste basins are currently maintained at an acceptable level by pumping into the main canals for the EAA. The main canals for the EAA have higher water levels than the mill canals. U.S. Sugar Corporation proposes to eliminate pumping from the mill canals to the EAA canals and, instead, pump water into on-site bermed storage/evaporation basins. In addition, "finger ponds" are being constructed to filter/treat wastewater to allow large-scale reuse on-site.

Other Treatment Alternatives

A preliminary assessment of several potential treatment alternatives for sugar mill waste streams was performed. Four alternative technologies were evaluated on general economic and noneconomic criteria: (1) wetlands treatment, (2) chemical treatment followed by sedimentation, (3) deep well injection, and (4) percolation ponds. Table 4-2 presents a summary of the results of this assessment.

Wetlands treatment, deep well injection, and percolation ponds can be eliminated from consideration as stand-alone options (i.e., not coupled with other technologies). Wetlands treatment does not have the capability to provide treatment for liquids with high phosphorus concentrations or for the high solids-content sludge waste streams. Deep well injection would require reduction of solids content of the waste stream. Percolation ponds have the ability to provide some reduction of phosphorus concentration, mainly through soil removal mechanisms. However, phosphorus concentrations in the treated seepage from the percolation ponds will be much higher than that achievable through the other alternatives (especially for the sludge ponds because of the extremely high influent phosphorus concentrations). In addition, phosphorus removal capacities of the soils surrounding the percolation ponds will be used up rather quickly. Consequently, percolation ponds are considered a short-term solution.

Chemical treatment is possible as a stand-alone option but does not appear feasible because of the extremely large amounts of chemicals that would be required for the very high phosphorus and high solids waste streams from the sugar mills.

Table 4-2 Summary of Preliminary Alternatives Assessment

Treatment technology	Advantages	Disadvantages	Potential effluent phosphorus concentration
Wetlands	Adequate as a polishing treatment only	Large amount of land required High monitoring cost Moderately poor reliability Does not address sludge waste streams	0.05 (only if influent is <1 mg/l phosphorus)
Chemical treatment followed by sedimentation	Very good phosphorus-removal capability Moderate cost option Good reliability	Moderate amount of land required High operation cost Requires moderately skilled operators	1 mg/l
Deep well injection	Completely diverts phosphorus-load Very little land required Moderate operation cost Good reliability Relatively simple operation	High cost option May have some technical difficulties disposing of sludges Permanent loss of water resources	0 mg/l[a]
Percolation ponds	Low cost option Low operation cost Simple operation and maintenance	Poor phosphorus removal capability Moderate amount of land required Poor reliability	1 mg/l or more (effluent concentration depends greatly on influent concentration)

[a] Phosphorus loading to the EAA canals is 0 because wastewater does not reach the canals.

The best solutions are combinations of the proposed alternatives. Three feasible combinations include: (1) percolation ponds followed by chemical treatment, (2) percolation ponds followed by deep well injection, and (3) percolation ponds followed by chemical treatment and wetlands. Each of these alternatives uses the existing percolation ponds to reduce solids and phosphorus loading. The third alternative uses chemical treatment after percolation ponds to further reduce phosphorus concentration prior to wetlands treatment.

While each of these three alternatives is technically sound, there are varying costs, implementation requirements, and reliabilities associated with them. Percolation ponds followed by chemical treatment and wetlands requires a high level of monitoring and is the least reliable, most land intensive, and highest cost alternative. Percolation ponds followed by chemical treatment requires a fairly skilled operations staff and has a high operating cost. Percolation ponds followed by deep well injection is estimated to have a slightly higher capital cost than percolation ponds followed by chemical treatment; however, it requires very little land, has moderate operating costs, and is very reliable. However, deep well injection results in the permanent loss of water resources.

PACKAGE WASTEWATER TREATMENT PLANTS

Package plants are typically activated sludge plants serving small villages and labor camps. They are called package plants because they are usually purchased from a vendor that is able to sell whole units "off-the-shelf." Their primary goals are to reduce wastewater solids and organic concentrations at minimum costs and with minimum operator attention. Extended aeration systems are popular because they can achieve these goals, while producing a sludge that is highly oxidized and can be disposed of without creating odors and other nuisances.

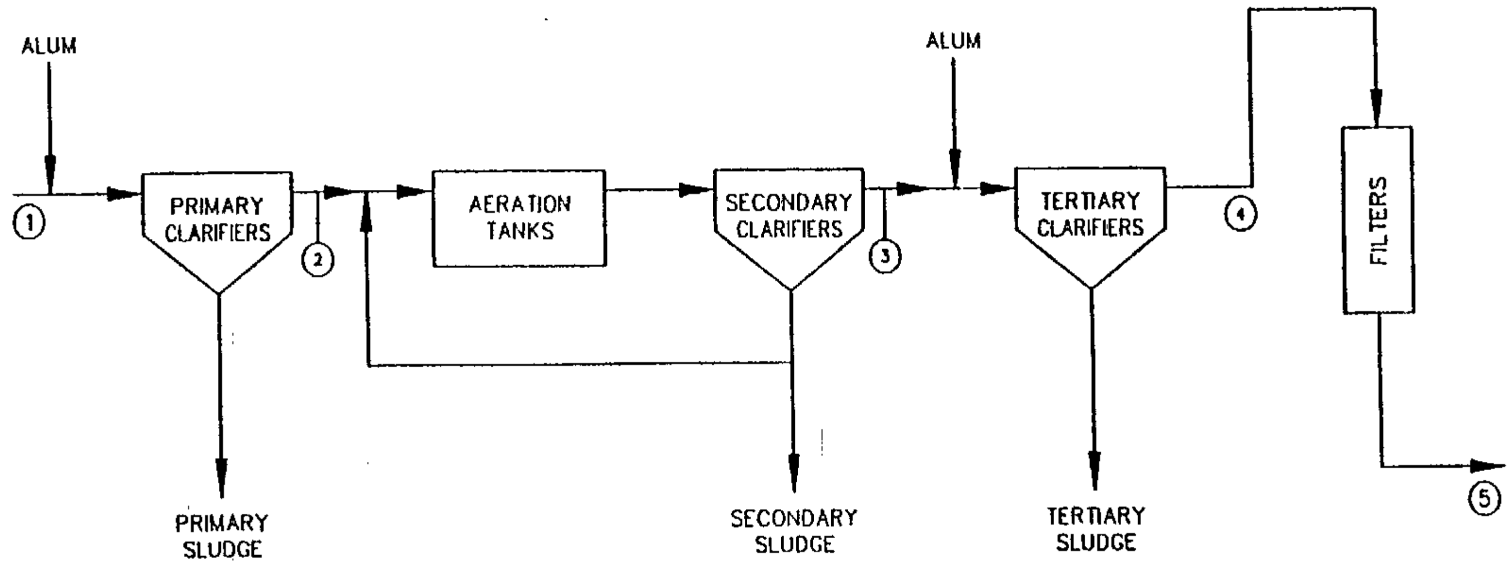
Few, if any, package plants are designed or operated for phosphorus removal. Some phosphorus is taken up by the activated sludge microorganisms during their growth. Phosphorus is removed from the system when the excess growth is wasted. Low phosphorus residuals (<2 mg/l) are not attained by biological uptake alone unless the wastewater phosphorus is initially low (3 to 5 mg/l) or unless the system is operated in a special mode (luxury phosphorus uptake) where higher than normal phosphorus uptakes are obtained. A luxury phosphorus uptake system demands a high level of operator attention and skill.

Three approaches are considered for enhanced phosphorus removal at package plants: (1) treatment of package plant effluent in a follow-on wetland, (2) chemical addition to existing process units or follow-on sedimentation tanks, and (3) direct filtration. Chemical addition to existing is the recommended method. It is commonly used and is the least costly method because the major treatment units are already in place.

Typically, iron or aluminum salts are added into the inlet of the primary clarifier. If the system does not have a primary clarifier (which is the case for many package plants), iron or aluminum salts are added into the inlet of the aeration tank. Metal to phosphorus molar ratios of 0.5 to 0.9 are typical. The combination of biological uptake and chemical precipitation are sufficient to reduce phosphorus concentrations to the 0.5 to 2 mg/l range.

Phosphorus concentrations can be further reduced by adding downstream treatment units. For example, the Durham Plant in Washington County, Oregon combines tertiary alum addition/clarification and filtration with alum treatment in the existing system to reduce phosphorus concentrations to 0.04 to 0.12 mg/l. The Rock Creek Plant, also in Washington County, achieves the same results, but does not use filtration. Figure 4-1 shows pertinent results for the Durham and Rock Creek Plants.

Incremental phosphorus reductions achieved by adding downstream equipment are costly. Tertiary treatment (including filtration) is probably beyond the operating and financial capabilities of most entities now using package plants. Chemical addition within existing treatment units is the most realistic and cost-effective method of reducing phosphorus discharges from EAA package plants. Chemical addition should also increase removals of other pollutants (e.g., suspended solids and BOD_5).



NO.	ITEM	DURHAM	ROCK CREEK
1	INFLUENT		
	P, mg/L	8.1 - 14.3	6.5 - 9.7
	ALUM DOSE[a], mg/L	100 - 148	79 - 118
	Al/P MOLE RATIO	0.45 - 0.85	0.63 - 0.65
2	PRIMARY EFFLUENT P, mg/L	0.5 - 4.5	2.1 - 2.4
3	SECONDARY EFFLUENT		
	P, mg/L	0.2 - 2.1	0.2 - 2.5
	ALUM DOSE, mg/L	40	52 - 65
	Al/P MOLE RATIO	2.5 - 9.9	5.4 - 14.1
4	TERTIARY EFFLUENT P, mg/L	0.07 - 0.27	0.04 - 0.09
5	FILTER EFFLUENT P, mg/L	0.04 - 0.12	N/F[b]

a ALUM = $AL_2(SO_4)_3 14H_2O$

b N/F = NO FILTER AT ROCK CREEK

Brown and Caldwell Consultants

E:/7138/FIG4-1

FIGURE 4-1.
REMOVALS IN TWO ACTIVATED SLUDGE PLANTS USING CHEMICAL PRECIPITATION

MUNICIPAL WASTEWATER TREATMENT PLANTS

The four municipal wastewater treatment plants within the study area are located in Belle Glade, Okeechobee, Pahokee, and South Bay. The City of Clewiston is located northwest of Basin S-8 and its wastewater treatment and disposal practices will not impact surface water quality in the EAA. Wastewater treatment plant operators were contacted to determine the characteristics of the treatment process such as flow rate, influent and effluent phosphorus concentrations, and the disposal of effluent and sludge.

Belle Glade

The City of Belle Glade operates a 3.0-million-gallon-per-day (mgd) secondary wastewater treatment facility. The average daily flow rate in 1988 was 2.2 mgd. In 1988, the average concentration of phosphorus in raw sewage entering the plant was 8.3 mg/l. After treatment, the concentration of the effluent was reduced to 5.2 mg/l. Annual phosphorus loadings discharged to surface waters in 1988 equalled 17.5 tons and an estimated 10.5 tons of phosphorus was in sludge exported to Okeechobee County where it was applied to pastureland. At present, treated effluent is discharged via deep well injection.

Okeechobee

The City of Okeechobee operates a 0.6-mgd contact stabilization wastewater treatment plant. Effluent is discharged onto a 310-acre field of improved pasture through a spray irrigation system. The average daily flow rate in 1987 was 0.3 mgd. The phosphorus concentration of treated effluent was reported at approximately 3.2 mg/l. A loading of about 1.5 tons of phosphorus per year is applied to the spray fields. The remaining phosphorus is deposited in sludge which is landspread on pastures in Okeechobee County.

Pahokee

The City of Pahokee operates a 1.2-mgd secondary wastewater treatment plant. The average daily flow rate in 1988 was 1.1 mgd. In 1988, the average concentration of phosphorus in the raw sewage entering the plant was 6.3 mg/l. After treatment, the concentration of the effluent was reduced to 2.6 mg/l. Annual phosphorus loadings discharged to surface waters in 1988 equalled 4.3 tons and an estimated 6.2 tons of phosphorus was in sludge which was spread on land adjacent to the treatment plant. At present, the City uses deep well injection as the method of effluent disposal.

South Bay

The City of South Bay operates a 0.6-mgd secondary wastewater treatment plant which discharges treated effluent to percolation ponds with overflow to lateral canals in the S-2 drainage basin. Federal Department of Environmental Regulation estimated that approximately 1.5 tons of phosphorus enter drainage waters each year due to overflows. Treated effluent is injected from deep wells. Sludge is landspread on pasture adjacent to the treatment plant.

Summary of Municipal Wastewater Treatment Plants

Three of the four municipal wastewater treatment plants within the EAA use deep well injection of treated effluent for disposal. Effluent injected into deep aquifers below the limestone caprock will not impact surface agricultural drainage waters emanating from the EAA and will not be of concern in evaluating treatment technologies to reduce phosphorus concentration to 0.05 mg/l. Domestic wastewater sludges produced during treatment and placed on land adjacent to the treatment plants will be controlled by existing Federal regulations contained in 40 CFR Part 503.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes our evaluation of alternative treatment technologies to reduce the concentration of total phosphorus to 0.05 mg/l in waters leaving the Everglades Agricultural Area (EAA). The evaluation included alternatives on the basin and farm scales and for point sources of wastewater in the EAA.

BASIN-SCALE TREATMENT ALTERNATIVES

Direct filtration, chemical treatment with wetlands, and chemical treatment were evaluated and compared with the Stormwater Treatment Areas (STAs) presently proposed for treating agricultural drainage flows from the EAA.

Direct Filtration

Direct filtration appears to be an attractive alternative to STAs for the following reasons:

1. **Lower Cost.** Capital, operation and maintenance (O&M), and present worth costs are lower for direct filtration than STAs. Costs vary with the filtration rate. If high-rate direct filtration at a maximum rate of 11 gpm/sq ft is proven feasible by means of pilot tests, and sludge can be disposed on dedicated land adjacent to the treatment plant, significant cost savings can be achieved. The present worth of constructing and operating high-rate direct filtration plants for 20 years is shown below compared with the cost of constructing and operating STAs:

Basin	Direct filtration	STA
S-5A	$110 million	$153 million
S-7	$48 million	$82 million

2. **Less Land Required.** Direct filtration requires 424 acres of land, including sludge disposal, at Basin S-5A, while the STA requires 12,200 acres. At Basin S-7, direct filtration requires 186 acres, while the STA requires 6,220 acres. This means not only lower capital costs for the purchase of land, but also less revenue loss to the community as a result of not removing nearly as much agricultural land from production.

3. **Proven Technology.** Direct filtration has been used to treat surface runoff waters for decades. The Wahnbach Reservoir direct filtration plant in Germany has been treating agricultural drainage water to reduce phosphorus from about 0.2 to 0.005 mg/l for 15 years in a situation similar to the EAA. The ability of the STAs to reduce

phosphorus concentration in the EAA is based on the transferability of research performed on WCA 2A. Critical design instruction from the Everglades Nutrient Removal Project will not be available in time to address many of the questions concerning the STA design criteria prior to the time that design of the recommended alternative must begin.

4. **Immediate Phosphorus Removal.** When the direct filtration plant is placed in operation, it will immediately reduce phosphorus concentrations to 0.05 mg/l. There will be no long start-up period required to reach steady state equilibrium before phosphorus can be removed to the proper level as with the STAs.

5. **Extended Operation.** With proper O&M and periodic replacement of worn-out equipment, the direct filtration plants will perform indefinitely. The useful life of the STAs has not been determined.

6. **Low Phosphorus Levels.** The design of the direct filtration system is based on achieving an effluent phosphorus concentration of 0.010 mg/l or one-fifth of the target concentration of 0.050 mg/l. For Basin S-5A, this low phosphorus concentration will be achieved on 74 percent of the flowdays based on discharge data for the period of record. For Basin S-7, 56 percent of the flowdays are below the treatment plant capacity and, therefore, are treated to the .010 mg/l level.

7. **Expandability and Flexibility.** The direct filtration system provides the District with the flexibility to construct systems in modules, thus avoiding the initial cost of constructing an entire system. Modular construction also offers flexibility for adjusting to reduced flows and phosphorus loads that exceed the target levels for on-farm best management practices. In addition, direct filtration, unlike STAs, is not limited by a phosphorus retention capability, so that lake releases and other non-EAA generated flows could be included more economically in the design. The ability to achieve low phosphorus levels also provides the flexibility to meet possible future regulation requirements for phosphorus discharges from the EAA. Finally, phosphorus levels could be reduced significantly by the use of equalization preceding the treatment system without modifying the treatment system itself.

Chemical Treatment with a Wetland

The chemical treatment with a wetland alternative for Basin S-5A does not appear to be an attractive option. In this alternative, chemical pretreatment is used to remove some of the phosphorus (from 0.187 to 0.1 mg/l) prior to flow through a wetland. The capital cost and present worth of chemical treatment with a wetland, including dedicated land disposal of sludge, are more than the STA; the annual O&M costs are comparable. The present worth of chemical treatment with a wetland is $205 million compared with $153 million for the STA. The land required for the chemical treatment with a wetland is 6,200 acres compared with 12,200 acres for the STA.

Chemical Treatment

The chemical treatment alternative for Basin S-7 is an attractive alternative compared with the STA; however, it is not as attractive when compared with direct filtration. The capital, O&M, and present worth costs are all lower for chemical treatment than for the STA. The present worth for chemical treatment, including dedicated land disposal of sludge, is $74 million compared with $82 million for the STA. The land required for chemical treatment is 470 acres compared with 6,220 acres for the STA. The other advantages cited above for direct filtration also apply to chemical treatment at Basin S-7.

Recommendations

The following are recommendations concerning the basin-scale alternative treatment technologies:

1. Direct filtration should be considered a viable alternative to STAs in all basins of the EAA. Direct filtration should be included in the upcoming Plan Formulation phase of the Everglades Protection Project.

2. Bench-scale and pilot plant testing of the direct filtration process on EAA waters should proceed immediately.

Bench Testing. Bench testing can assure that the proposed treatment system will achieve the predicated level of treatment with EAA drainage. Bench testing also enables the optimization of process chemistry, provides confirmation of the effects of treatment on effluent water quality, and provides initial assessments of sludge composition.

The specific objectives of bench-scale testing are to:

1. Distinguish between the effectiveness of various primary coagulants.

2. Determine minimum primary coagulant doses needed to produce necessary phosphorus reductions.

3. Find the pH range for optimum phosphorus reduction and coagulation and determine acid/base doses needed to achieve the range.

4. Optimize mixing time and mixing intensity.

5. Verify water quality effects predicted in Table A-1 in Appendix A of this report.

6. Determine sludge composition.

These objectives would be achieved by jar testing with EAA drainage water. The water samples would be dosed with selected coagulants over specified ranges of chemical dose and reaction pH. The flocculated water would be passed through filter paper to simulate filtration. The filtrate would be analyzed for parameters of interest.

Estimates of sludge composition would be made through a mass balance considering the flows and composition of the untreated and treated water and reagent considering doses. If the estimated sludge composition is such that the calculated concentrations of regulated parameters in leachate from a hypothetical Toxic Characteristics Leaching Procedure (TCLP) could not exceed toxic limits even if the contaminants were totally extracted, then one could conclude that the sludge cannot be a toxic waste. If the calculated concentrations exceed the toxic limits, then the sludge may be a hazardous waste, depending on the percentage of contaminants that can be leached under actual test conditions. This percentage would have to be determined empirically during pilot testing when enough sludge is generated to satisfy TCLP sample weight requirements.

Pilot Testing. Pilot testing would confirm the ability of the system to operate reliably and effectively under the variations of flow and composition expected in the EAA. It also would provide sufficient sludge quantities for the TCLP test. Furthermore, it would provide opportunities to precisely define design parameters to determine the appropriate filtration rate. The use of high-rate filtration could save as much as $25 million in direct filtration life-cycle costs in Basin S-5A alone or a projected $60 to $90 million in life-cycle costs for the four basins.

The specific objectives of pilot testing would be to:

1. Test alternative filter media configurations and modes of operation.

2. Determine how filter feedwater rate, feedwater suspended solids concentration, coagulant and filter aid dose, and mixing times and intensity affect run length and filtrate quantity with each media configuration.

3. Develop strategies to minimize solids breakthrough during flow surges.

4. Develop efficient cleaning procedures for each filter media configuration.

5. Test sludges for toxicity characteristics through the TCLP.

Several filters, each employing different media configurations, would be run in parallel on a common feedwater to allow a direct comparison of media performance. The filters would be run until solids breakthrough or terminal head loss, whichever occurs first. Pressure taps located along the length of each filter bed would allow the determination of where within the bed the media is clogging, and to make necessary changes to the media design. Different media cleaning methods would be tested.

FARM-SCALE TREATMENT ALTERNATIVES

Chemical treatment systems with sedimentation basins appears to be a viable alternative to farm treatment areas (FTAs). They would require less land than FTAs and compare favorably with FTAs in present worth costs. In-canal chemical treatment does not appear feasible. The in-canal system has a lower degree of performance and reliability (relative to chemical treatment systems with sedimentation basins) which require it to treat larger portions of the flow, thereby increasing the costs.

For the sugarcane farms, the cost per pound of phosphorus removed will generally be higher for farm-scale alternatives than for basin-scale alternatives, reflecting the former's economy-of-scale disadvantages. For the vegetable farm treatment systems, the per pound costs are significantly lower than the cost for the basin-scale alternatives. However, the vegetable farm discharges do not reduce the concentration of phosphorus to the required 0.050 mg/l level. The discharge from these farms would require treatment in a basin-scale system to achieve the full phosphorus reduction required. The overall cost effectiveness of the vegetable farm-scale systems needs to be considered as the plan formulation phase develops.

POINT SOURCE TREATMENT ALTERNATIVES

Wetlands, chemical treatment, deep well injection, and percolation ponds are possible treatment technologies for the seven sugar mills. Deep well injection eliminates phosphorus discharges to surface waters of the EAA, but it also reduces flow to them. Chemical treatment can reduce sugar mill waste stream phosphorus concentrations from between 20 and 30 mg/l to 1 mg/l. Percolation pond effluent phosphorus concentration depends largely on the concentration of phosphorus in the influent stream. Wetlands with chemical pretreatment can reduce phosphorus concentrations to less than 1 mg/l. However, wetlands require considerable land area which would be taken from agricultural production. In reality, many of the sugar mills are planning to reduce phosphorus discharges by retaining process wastewater on-site and recycling it to the maximum extent possible.

It is anticipated that the Florida Department of Environmental Regulation (FDER) will ultimately regulate phosphorus discharges from sugar mills and that the discharge limit for phosphorus will be low. Consequently, technologies such as chemical treatment and percolation ponds that can achieve low effluent concentrations without taking up a lot of land will probably be favored. However, decisions regarding which technology is most appropriate for each mill will need to be determined on the basis of individual site conditions and treatment requirements.

Ferric chloride or alum addition to the existing package wastewater treatment plants is the least expensive way of reducing phosphorus concentrations in the plant effluents to the 0.5 to 2 mg/l range. This approach should be confirmed through demonstration tests at actual plants in the EAA.

The results of the tests could be used by the FDER to establish effluent phosphorus concentration limits for the package plants.

All four municipal wastewater treatment plants in the EAA use (or will use in the near future) deep well injection for effluent disposal. Therefore, these discharges will have no impact on water quality in surface waters of the EAA.

APPENDIX A

IMPACTS OF DIRECT FILTRATION ON EFFLUENT WATER QUALITY

WATER QUALITY EFFECTS

Table A-1 shows the concentrations of regulated water-quality parameters in discharges from Basins S-5A and S-7 (EAA discharge), how those concentrations are expected to change as the result of treatment by direct filtration, calculates the resultant treated water concentrations, and lists relevant Florida water quality standards. Concentrations are expressed in milligrams per liter (mg/L), unless indicated otherwise.

The EAA discharge concentrations are averaged values obtained from the District's Oracle Water Quality Data Base. The expected treatment-caused concentration changes were calculated using stoichiometry (chlorides, total dissolved solids), a computerized equilibrium water chemistry model (pH, alkalinity), and our in-house adsorption models (heavy metals).

Treated effluent composition is the composition of water issuing directly from the treatment units. Note that treated waters are not discharged directly, but blended with water that is bypassed around the treatment units. The treated and bypassed waters are then recombined. The recombined water (which must satisfy P discharge requirements of 0.05 mg/L) is the water which is discharged to the EAA. The blended water composition is intermediate between the composition of the treated and untreated waters. It is this blended water composition that should be compared with the water quality standards.

Florida water quality Class I standards apply to potable water supplies, for example, water in the water conservation areas. Florida Class III standards apply to recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

Table A-1 shows that direct filtration is expected to cause no significant changes in water composition. Minimal changes occur because direct filtration needs very low chemical doses to effect the desired degree of P removal. Total dissolved solids (TDS) is the only parameter expected to exceed water quality standards, and that will occur only because TDS is already well above Class I limits in the untreated water.

In addition to removing P, treatment will reduce the concentrations of some heavy metals (cadmium and zinc) which are now close to or above water quality standards. Addition of iron as a reagent will not increase effluent iron levels, in fact the untreated water iron concentration will be reduced. This result accrues because virtually all iron in the untreated water is particulate iron, and virtually all reagent iron will be converted to particulate form by precipitation. The particulate iron will be nearly all removed by the filters.

Table A-1 Comparison of Direct Filtration Influent and Treated Water Composition and Florida Water Quality Standards (continued)

Parameter[a]	EAA Discharge		Expected Changes Caused By Treatment	Treated Effluent		Blended Effluent		FDER Water Quality Standards		Comment
	S-5A	S-7		S-5A	S-7	S-5A	S-7	Class I	Class III	
Nickel, µg/L	9.2	6.5	None	9.2	6.5	9.2	6.5	100	100	
Nitrate, as N	1.63	0.8	None					10	—	Dentrification (for nitrogen removal) could be obtained in filters if methanol is added to filter influent.
Nutrients	—	—						[e]	[e]	P reduced significantly.
Pesticides and herbicides	—	—	Minor reductions	—	—	—	—	[f]	[f]	
PCBs, µg/L	—	—	Minor reductions	—	—	—	—	1	1	
pH, units	7.2	7.2	-0.2, -0.1	7.0	7.1	7.05	7.15	—	[g]	
Selenium, µg/L	—	—	Minor reductions	—	—	—	—	10	10	
Silver, µg/L	—	—	None					70	70	
Transparency	—	—	Improvement	—	—	—	—	[h]	[h]	
Zinc, µg/L	32	24	-15	17	9	20	16	30	30	Treatment may reduce zinc to satisfy water quality standards.

[a]Parameters expressed in milligrams per liter (mg/L), unless noted otherwise.
[b]Shannon Weaver diversity index of benthic macro invertebrates shall not be reduced to less than 75 percent of background levels as measured using organisms retained by a U.S. No. 30 sieve.
[c]Assumes use of 16 mg/L $FeCl_3$.
[d]Total dissolved solids estimated from specific conductance measurements.
[e]In no case shall nutrient concentrations be altered so as to cause an imbalance in natural populations of flora and fauna.
[f]Available on request.
[g]pH shall not vary by more than one unit from natural background.
[h]Not reduced 10 percent below background level.

APPENDIX B

CAPITAL COST ESTIMATES FOR BASIN-SCALE ALTERNATIVES

The attached cost summaries were generated with BACPAC, Brown and Caldwell's computerized cost estimating and scheduling program.

BROWN AND CALDWELL, CONSULTANTS, CONSTRUCTION MANAGEMENT DIVISION

**** ESTIMATE SUMMARY SHEET ****

ESTIMATE #: 7138A1
JOB #: 7138-05
EST DATE: 12-15-92
PRT DATE: 2-12-93
PRT TIME: 11:54 am

Project: FLORIDA EVERGLADES PROJECT
HIGH RATE FILTRATION, BASIN S5A
MADE BY: R.E. MILLARD
CHKD BY: ____________

================
SUMMARY TOTALS
================

Labor:	$10,855,405	Sales Tax:	$ 1,732,611
Material:	$28,876,852	Markup:	$ 6,390,120
Subs:	$13,078,305	Subtotal:	$63,575,041
Equipmnt:	$ 2,641,747	Bond:	$ 635,750
		Revised Subtotal:	$64,210,791
		Gross Sales Tax:	$
		Grand Total:	$64,210,791

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MARKUP DATA
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Labor M/U:	18.00%	Sales Tax (Mat'l):	6.00%
Material M/U:	12.00%	Sales Tax (Equip):	.00%
Subs M/U:	5.00%	Bond Rate:	1.00%
Equipmnt M/U:	12.00%	Gross Sales Tax:	.00%

GRP#	Process Area	<------Labor------> M/C Hrs	Amount($)	Material Amount($)	Sub Amount($)	Equipment Amount($)	Sales Tax($)	Markup($)	Total($)	Job
010	CONTRACTOR INDIRECTS	33,504	861,333	2,496	261,300	328,025	150	207,768	1,661,071	2.6
012	INFLUENT CHANNEL	2,150	41,545	60,240	27,600	43,412	3,614	21,296	197,704	.3
015	YARD DEVELOPMENT	2,857	51,519	168,616	668,325	853	10,117	63,026	962,454	1.5
020	INFLUENT PUMP STATION	19,689	444,715	3,998,540	555,396	21,970	239,916	590,281	5,850,813	9.2
024	WATER FEED CHANNEL	16,916	300,131	385,498		56,049	23,133	107,009	871,820	1.4
027	RAPID MIX TANK	11,557	217,102	422,359		17,401	25,340	91,852	774,058	1.2
028	FLOCCULATION	22,246	426,485	920,546	15,000	54,331	55,235	194,142	1,663,737	2.6
030	FILTERS	363871	6,795,388	16,791,065	127,500	1,048,493	1007464	3,369,930	29,137,842	45.8
035	CHEMICAL TREATMENT	3,922	87,583	485,250		7,791	29,117	74,929	684,666	1.1
038	BACKWASH SYSTEM	13,697	294,090	2,423,664		23,551	145,420	346,602	3,233,324	5.1
042	SLUDGE STORAGE	4,103	90,403	254,901	88,320	95,767	15,294	62,769	607,452	1.0
045	SLUDGE HOLDING TANK	21,679	370,459	777,849	28,980	72,347	46,673	170,153	1,466,460	2.3
046	LAND DISPOSAL	8,957	193,743		471,500	146,279		76,002	887,524	1.4
086	EFFLUENT CHANNEL	16,028	330,942	284,152	124,200	721,982	17,049	186,516	1,664,837	2.6
172	YARD PIPING	9,380	252,697	1,525,000			91,500	228,485	2,097,683	3.3
176	ELECTRICAL/INSTRUMENTS	.			10,500,000			525,000	11,025,000	17.3
204	CENTRAL PLANT BUILDING	4,108	101,270	376,686	210,184	3,499	22,600	74,362	788,600	1.2
	Estimate Subtotal:	554665	$10,855,405	$28,876,852	$13,078,305	$ 2,641,747	*******	6,390,120	$63,575,041	100.0
	Plus Bond, If Reqd:								$ 635,750	1.0
	Revised Subtotal:								$64,210,791	101.0
	Plus Gross Sales Tax, If Reqd:								$	.0
	GRAND TOTAL:								$64,210,791	

**** ESTIMATE SUMMARY SHEET ****

Project: FLORIDA EVERGLADES PROJECT
LOW RATE FILTRATION, BASIN S5A
MADE BY: R.E. MILLARD
CHKD BY: ___________

ESTIMATE #: 7138A
JOB #: 7138-05
EST DATE: 12-15-92
PRT DATE: 2-12-93
PRT TIME: 11:52 am

****
SUMMARY TOTALS
****

Labor:	$14,863,309	Sales Tax:	$ 2,229,567
Material:	$37,159,450	Markup:	$ 8,186,319
Subs:	$13,153,305	Subtotal:	$78,876,320
Equipmnt:	$ 3,284,370	Bond:	$ 788,763
		Revised Subtotal:	$79,665,083
		Gross Sales Tax:	$
		Grand Total:	$79,665,083

****
MARKUP DATA
****

Labor M/U:	18.00%	Sales Tax (Mat'l):	6.00%
Material M/U:	12.00%	Sales Tax (Equip):	.00%
Subs M/U:	5.00%	Bond Rate:	1.00%
Equipmnt M/U:	12.00%	Gross Sales Tax:	.00%

GRP#	Process Area	Labor M/C Hrs	Labor Amount($)	Material Amount($)	Sub Amount($)	Equipment Amount($)	Sales Tax($)	Markup($)	Total($)	.
010	CONTRACTOR INDIRECTS	33,504	861,333	2,496	261,300	328,025	150	207,768	1,661,071	2
012	INFLUENT CHANNEL	2,150	41,545	60,240	27,600	43,412	3,614	21,296	197,704	
015	YARD DEVELOPMENT	2,857	51,519	168,616	668,325	853	10,117	63,026	962,454	1
020	INFLUENT PUMP STATION	19,689	444,715	3,998,540	555,396	21,970	239,916	590,281	5,850,813	7
024	WATER FEED CHANNEL	16,916	300,131	385,498		56,049	23,133	107,009	871,820	1
027	RAPID MIX TANK	11,557	217,102	422,359		17,401	25,340	91,852	774,058	1
028	FLOCCULATION	22,246	424,485	920,546	15,000	54,331	55,235	194,142	1,663,737	2
030	FILTERS	577472	10,801,294	25,073,662	202,500	1,691,116	1504420	5,166,131	44,439,121	56.
035	CHEMICAL TREATMENT	3,922	87,583	485,250		7,791	29,117	74,929	684,666	.
038	BACKWASH SYSTEM	13,697	294,090	2,423,664		23,551	145,420	346,602	3,233,324	4.
042	SLUDGE STORAGE	4,103	90,403	254,901	88,320	95,767	15,294	62,769	607,452	.
045	SLUDGE HOLDING TANK	21,679	370,459	777,849	28,980	72,347	46,673	170,153	1,466,460	1.
046	LAND DISPOSAL	8,957	193,743		471,500	146,279		76,002	887,524	1.
086	EFFLUENT CHANNEL	16,028	330,942	284,152	124,200	721,982	17,049	186,516	1,664,837	2.
172	YARD PIPING	9,380	252,697	1,525,000			91,500	228,485	2,097,683	2.
176	ELECTRICAL/INSTRUMENTS				10,500,000			525,000	11,025,000	14.
204	CENTRAL PLANT BUILDING	4,108	101,270	376,686	210,184	3,499	22,600	74,362	788,600	1.
	Estimate Subtotal:	768271	$14,863,309	$37,1[illegible],450	$13,153,305	$ 3,284,370	*******	8,186,319	$78,876,320	100.
	Plus Bond, If Reqd:								$ 788,763	1.
	Revised Subtotal:								$79,665,083	101.
	Plus Gross Sales Tax, If Reqd:								$	.
	GRAND TOTAL:								$79,665,083	

BROWN AND CALDWELL, CONSULTANTS, CONSTRUCTION MANAGEMENT DIVISION

****** ESTIMATE SUMMARY SHEET ******

ESTIMATE #: 713801
JOB #: 7138-05
EST DATE: 12-15-92
PRT DATE: 2-12-93
PRT TIME: 9:56 am

Project: FLORIDA EVERGLADES PROJECT
HIGH RATE FILTRATION, BASIN S7
MADE BY: R.E. MILLARD
CHKD BY: ____________

SUMMARY TOTALS

Labor:	$ 4,653,881	Sales Tax:	$ 685,113
Material:	$11,418,547	Markup:	$ 2,765,713
Subs:	$ 7,347,912	Subtotal:	$28,457,771
Equipmnt:	$ 1,586,606	Bond:	$ 284,578
		Revised Subtotal:	$28,742,349
		Gross Sales Tax:	$
		Grand Total:	$28,742,349

MARKUP DATA

Labor M/U:	18.00%	Sales Tax (Mat'l):	6.00%
Material M/U:	12.00%	Sales Tax (Equip):	.00%
Subs M/U:	5.00%	Bond Rate:	1.00%
Equipmnt M/U:	12.00%	Gross Sales Tax:	.00%

GRP#	Process Area	Labor M/C Hrs	Labor Amount($)	Material Amount($)	Sub Amount($)	Equipment Amount($)	Sales Tax($)	Markup($)	Total($)	Jo
010	CONTRACTOR INDIRECTS	20,240	520,079	1,456	156,745	197,775	87	125,360	1,001,502	3.5
012	INFLUENT CHANNEL	2,150	41,545	60,240	27,600	43,412	3,614	21,296	197,704	.7
015	YARD DEVELOPMENT	1,955	36,804	133,167	562,395	514	7,992	50,788	791,656	2.8
020	INFLUENT PUMP STATION	15,020	343,498	3,119,592	385,485	16,293	187,176	457,407	4,509,447	15.8
024	WATER FEED CHANNEL	4,735	84,034	107,961		15,690	6,476	29,965	244,132	.9
027	RAPID MIX TANK	3,205	60,088	115,305		4,874	6,917	25,237	212,414	.7
028	FLOCCULATION	6,417	122,921	275,177	15,000	16,193	16,511	57,838	503,646	1.8
030	FILTERS	144037	2,575,884	4,586,460	60,000	470,445	275,188	1,073,487	9,041,466	31.8
035	CHEMICAL TREATMENT	2,049	50,133	354,027		2,181	21,242	51,769	479,350	1.7
038	BACKWASH SYSTEM	3,719	79,512	629,852		6,593	37,790	90,687	844,432	3.0
042	SLUDGE STORAGE	1,555	35,299	248,852	24,730	26,814	14,931	40,670	391,295	1.4
045	SLUDGE HOLDING TANK	6,601	112,001	417,455	8,114	20,259	25,050	73,091	655,965	2.3
046	LAND DISPOSAL	2,508	54,247		326,420	40,958		31,001	452,626	1.6
086	EFFLUENT CHANNEL	16,028	330,942	284,152	124,200	721,982	17,049	186,516	1,664,837	5.9
172	YARD PIPING	4,690	126,349	762,500			45,750	114,243	1,048,841	3.7
176	ELECTRICAL/INSTRUMENTS				5,500,000			275,000	5,775,000	20.3
204	CENTRAL PLANT BUILDING	3,257	80,546	322,351	157,224	2,630	19,341	61,357	643,453	2.3
	Estimate Subtotal:	238171	$ 4,653,881	$11,418,547	$ 7,347,912	$ 1,586,606	685113	2,765,713	$28,457,771	100.0
	Plus Bond, If Reqd:								$ 284,578	1.0
	Revised Subtotal:								$28,742,349	101.0
	Plus Gross Sales Tax, If Reqd:								$	.0
	GRAND TOTAL:								$28,742,349	

**** ESTIMATE SUMMARY SHEET ****

ESTIMATE #: 7138C1
JOB #: 7138-05
EST DATE: 12-15-92
PRT DATE: 2-12-93
PRT TIME: 9:54 am

Project: FLORIDA EVERGLADES PROJECT
LOW RATE FILTRATION, BASIN S7
MADE BY: R.E. MILLARD
CHKD BY: ____________

SUMMARY TOTALS

Labor:	$ 5,094,067	Sales Tax:	$ 828,981
Material:	$13,816,357	Markup:	$ 3,133,051
Subs:	$ 7,347,912	Subtotal:	$31,810,041
Equipmnt:	$ 1,589,673	Bond:	$ 318,100
		Revised Subtotal:	$32,128,141
		Gross Sales Tax:	$
		Grand Total:	$32,128,141

MARKUP DATA

Labor M/U:	18.00%	Sales Tax (Mat'l):	6.00%
Material M/U:	12.00%	Sales Tax (Equip):	.00%
Subs M/U:	5.00%	Bond Rate:	1.00%
Equipmnt M/U:	12.00%	Gross Sales Tax:	.00%

GRP#	Process Area	<------Labor------> M/C Hrs	Amount($)	Material Amount($)	Sub Amount($)	Equipment Amount($)	Sales Tax($)	Markup($)	Total($)	
010	CONTRACTOR INDIRECTS	20,241	520,366	1,456	156,745	197,775	87	125,411	1,001,840	
012	INFLUENT CHANNEL	2,150	41,545	60,240	27,600	43,412	3,614	21,296	197,704	
015	YARD DEVELOPMENT	1,955	36,804	133,167	562,395	514	7,992	50,788	791,656	2
020	INFLUENT PUMP STATION	15,020	343,498	3,119,592	385,485	16,293	187,176	457,407	4,509,447	14
024	WATER FEED CHANNEL	4,735	84,034	107,961		15,690	6,476	29,965	244,132	
027	RAPID MIX TANK	3,205	60,088	115,305		4,874	6,917	25,237	212,414	
028	FLOCCULATION	6,417	122,921	275,177	15,000	16,193	16,511	57,838	503,646	1
030	FILTERS	161360	3,015,784	6,984,268	60,000	473,512	419,056	1,440,774	12,393,398	39
035	CHEMICAL TREATMENT	2,049	50,133	354,027		2,181	21,242	51,769	479,350	1
038	BACKWASH SYSTEM	3,719	79,512	629,852		6,593	37,790	90,687	844,432	2
042	SLUDGE STORAGE	1,555	35,299	248,852	24,730	26,814	14,931	40,670	391,295	1
045	SLUDGE HOLDING TANK	6,601	112,001	417,455	8,114	20,259	25,050	73,091	655,965	2
046	LAND DISPOSAL	2,508	54,247		326,420	40,958		31,001	452,626	1
086	EFFLUENT CHANNEL	16,028	330,942	284,152	124,200	721,982	17,049	186,516	1,664,837	5.
172	YARD PIPING	4,690	126,349	762,500			45,750	114,243	1,048,841	3.
176	ELECTRICAL/INSTRUMENTS				5,500,000			275,000	5,775,000	18.
204	CENTRAL PLANT BUILDING	3,257	80,546	322,351	157,224	2,630	19,341	61,357	643,453	2.
	Estimate Subtotal:	255494	$ 5,094,067	$13,816,357	$ 7,347,912	$ 1,589,673	828981	3,133,051	$31,810,041	100.
	Plus Bond, If Reqd:								$ 318,100	1.
	Revised Subtotal:								$32,128,141	101.
	Plus Gross Sales Tax, If Reqd:								$	.
	GRAND TOTAL:								$32,128,141	

****** ESTIMATE SUMMARY SHEET ******

ESTIMATE #: 7138E1
JOB #: 7138-05
EST DATE: 1-15-93
PRT DATE: 2-12-93
PRT TIME: 11:56 am

Project: FLORIDA EVERGLADES PROJECT
CHEMICAL TREATMENT, BASIN S5A
MADE BY: R.E. MILLARD
CHKD BY: ____________

SUMMARY TOTALS

Labor:	$ 7,472,304	Sales Tax:	$ 996,601
Material:	$16,610,013	Markup:	$ 4,568,573
Subs:	$15,559,149	Subtotal:	$48,976,631
Equipmnt:	$ 3,769,991	Bond:	$ 489,766
		Revised Subtotal:	$49,466,397
		Gross Sales Tax:	$
		Grand Total:	$49,466,397

MARKUP DATA

Labor M/U:	18.00%	Sales Tax (Mat'l):	6.00%
Material M/U:	12.00%	Sales Tax (Equip):	.00%
Subs M/U:	5.00%	Bond Rate:	1.00%
Equipmnt M/U:	12.00%	Gross Sales Tax:	.00%

GRP#	Process Area	Labor M/C Hrs	Labor Amount($)	Material Amount($)	Sub Amount($)	Equipment Amount($)	Sales Tax($)	Markup($)	Total($)	Jo
010	CONTRACTOR INDIRECTS	33,504	861,333	2,496	261,300	328,025	150	207,768	1,661,071	3.[illegible]
012	INFLUENT CHANNEL	2,169	42,407	60,150	27,600	43,412	3,608	21,441	198,616	[illegible]
015	YARD DEVELOPMENT	2,878	47,327	172,458	622,322	12,630	10,348	61,847	926,930	1.[illegible]
020	INFLUENT PUMP STATION	18,655	421,360	3,392,365	511,312	19,873	203,542	510,879	5,059,331	10.[illegible]
027	RAPID MIX TANK	8,129	150,471	347,064		13,051	20,823	70,297	601,703	1.[illegible]
028	FLOCCULATION	166975	2,942,101	6,279,043		563,079	376,744	1,350,628	11,511,594	23.[illegible]
031	SEDIMENTATION BASIN	52,465	1,168,548	1,219,583	257,226	2,075,065	73,175	618,558	5,412,154	11.[illegible]
035	CHEMICAL TREATMENT	6,831	165,862	767,778		7,791	46,069	122,923	1,110,419	2.[illegible]
045	SLUDGE HOLDING TANK	21,675	370,396	777,838	28,980	72,345	46,673	170,141	1,466,370	3.[illegible]
046	LAND DISPOSAL	6,457	139,656		690,225	105,442		72,302	1,007,624	2.[illegible]
172	YARD PIPING	28,650	771,831	2,875,000			172,500	483,930	4,303,261	8.[illegible]
176	ELECTRICAL/INSTRUMENTS				12,950,000			647,500	13,597,500	27.[illegible]
204	CENTRAL PLANT BUILDING	4,108	101,270	376,686	210,184	3,499	22,600	74,362	788,600	1.[illegible]
205	CANAL INFLUENT CHANNEL	13,395	289,749	339,560		525,781	20,374	155,996	1,331,457	2.[illegible]
	Estimate Subtotal:	365892	$ 7,472,304	$16,610,013	$15,559,149	$ 3,769,991	996601	4,568,573	$48,976,631	100.[illegible]
	Plus Bond, If Reqd:								$ 489,766	1.[illegible]
	Revised Subtotal:								$49,466,307	101.[illegible]
	Plus Gross Sales Tax, If Reqd:								$	.[illegible]
	GRAND TOTAL:								$49,466,397	

**** ESTIMATE SUMMARY SHEET ****

ESTIMATE #: 7138F
JOB #: 7138-05
EST DATE: 12-15-92
PRT DATE: 2-12-93
PRT TIME: 12:0? pm

Project: FLORIDA EVERGLADES PROJECT
CHEMICAL TREATMENT, BASIN S7
MADE BY: R.E. MILLARD
CHKD BY: ____________

SUMMARY TOTALS

Labor:	$ 5,601,166	Sales Tax:	$ 836,258
Material:	$13,937,632	Markup:	$ 3,548,101
Subs:	$10,165,524	Subtotal:	$37,081,170
Equipmnt:	$ 2,992,490	Bond:	$ 370,812
		Revised Subtotal:	$37,451,981
		Gross Sales Tax:	$
		Grand Total:	$37,451,981

MARKUP DATA

Labor M/U:	18.00%	Sales Tax (Mat'l):	6.00%
Material M/U:	12.00%	Sales Tax (Equip):	.00%
Subs M/U:	5.00%	Bond Rate:	1.00%
Equipmnt M/U:	12.00%	Gross Sales Tax:	.00%

GRP#	Process Area	Labor M/C Hrs	Labor Amount($)	Material Amount($)	Sub Amount($)	Equipment Amount($)	Sales Tax($)	Markup($)	Total($)	Jo
010	CONTRACTOR INDIRECTS	33,504	861,333	2,496	261,300	328,025	150	207,768	1,661,071	4.
012	INFLUENT CHANNEL	2,169	40,160	60,150	27,600	43,412	3,608	21,036	195,965	.
015	YARD DEVELOPMENT	3,589	63,354	422,721	622,322	15,693	25,364	95,130	1,244,581	3.
020	INFLUENT PUMP STATION	16,782	383,788	3,248,976	480,768	17,342	194,939	485,078	4,810,890	13.
027	RAPID MIX TANK	3,674	84,374	254,032	36,225	1,828	15,244	47,706	439,405	1.
028	FLOCCULATION	95,969	1,735,194	5,143,031		329,334	308,581	969,021	8,485,163	22.
031	SEDIMENTATION BASIN	42,411	929,601	1,264,312	192,920	1,606,922	75,859	521,523	4,591,134	12.4
035	CHEMICAL TREATMENT	3,357	75,270	397,836		5,574	23,872	61,955	564,507	1.
045	SLUDGE HOLDING TANK	21,675	370,396	777,838	28,980	72,345	46,673	170,141	1,466,370	4.
046	LAND DISPOSAL	5,574	120,566		555,225	42,734		54,591	773,116	2.1
172	YARD PIPING	22,345	601,974	1,650,000			99,000	306,355	2,657,330	7.2
176	ELECTRICAL/INSTRUMENTS				7,750,000			387,500	8,137,500	21.
204	CENTRAL PLANT BUILDING	4,108	101,270	376,686	210,184	3,499	22,600	74,362	788,600	2.1
205	CANAL INFLUENT CHANNEL	13,395	233,882	339,560		525,781	20,374	145,940	1,265,535	3.4
	Estimate Subtotal:	268554	$ 5,601,166	$13,937,632	$10,165,524	$ 2,992,490	836258	3,548,101	$37,081,170	100.0
	Plus Bond, If Reqd:								$ 370,812	1.0
	Revised Subtotal:								$37,451,981	101.0
	Plus Gross Sales Tax, If Reqd:								$	.0
	GRAND TOTAL:								$37,451,981	

APPENDIX C

OPERATING AND MAINTENANCE COST ESTIMATES FOR BASIN-SCALE SYSTEMS

TABLE 1 OPERATING AND MAINTENANCE COSTS – S–5A LOW RATE DIRECT FILTERS

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
			0			0	0	0	0	0	0	0
			0				0	0			0	0
			0				0	0			0	0
Feed pumping	Average flow 149 mgd, 20 ft TDH		0			3700	66600	19980	34000	334000	233800	354380
			0				0	0			0	0
			0				0	0			0	0
Chemical delivery			0				0	0			0	0
FeCl3	Avg rate = 861 lb/hr, pure, Note A.	25000	1750	3772	471500	500	9000	2700	500		0	485450
Polymer #1	Avg. rate = 125 lb/day, Note A.	3000	210	11.5	46000	250	4500	1350	300		0	52360
Polymer #2	Avg. rate = 620 lb/day, Note A.	3000	210	56.5	45200	300	5400	1620	300		0	52730
			0				0	0			0	0
Rapid mix	Four tanks, total volume = 2566 cu ft, G = 750 sec−1, one–third time.	167000	11690			180	3240	972	200		0	16102
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Flocculation	Eight tanks, total volume = 233,000 cu ft, G = 50 sec−1, one–third time.	100000	7000			150	2700	810	4000		0	14510
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Filters (low rate)			0			35600	640800	192240	180000		0	993040
Structures	Eighty filter beds, 110,000 sq ft total area		0				0	0			0	0
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft.	1970000	137900			840	15120	4536	29000		0	186556
			0				0	0			0	0
			0				0	0			0	0
Backwash reservoir	Volume = 250,000 gal.		0			10	180	54	200		0	434
			0				0	0			0	0
Spent backwash basin/thickener	Volume = 57 million gallons, one dredge, operating half time		0			1300	23400	7020	2000	1600	1120	33540
			0				0	0			0	0
			0				0	0			0	0
Dedicated land disposal	Area = 335 acres, two subsurface sludge injection vehicles operating half time		0			2600	46800	14040	3000	1100	770	64610
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0.
Monitoring	People = 3		0			6240	112320	33696	8000		0	154016
			0				0	0			0	0
Operations bldg.	Area = 10,000 sq ft. Includes offices, laboratory, maintenance.	1000000	70000				0	0	20000		[illegible]	90000
			0				0	0			[illegible]	0
			0				0	0			0	0
Miscellaneous			0			0	0	0			0	0
			0				0	0			0	0
		3268000	228760	3840	562700	51670	930060	279018	261500	336700	235690	2497728

Notes

A. Chemicals, dollars/ton	
FeCl3 (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	16
D. Fuel, dollars/gal	0.7
E. Admin. & supv. [illegible]	[illegible]

TABLE 2 : OPERATING AND MAINTENANCE COSTS – S-5A HIGH RATE DIRECT FILTERS

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
			0			0	0	0	0	0	0	0
Feed pumping	Average flow 149 mgd, 20 ft TDH		0			3700	66600	19980	34000	334000	233800	354380
Chemical delivery			0				0	0			0	0
FeCl3	Avg. rate = 861 lb/hr, pure, Note A.	25000	1750	3772	471500	500	9000	2700	500		0	485450
Polymer #1	Avg. rate = 125 lb/day, Note A.	3000	210	11.5	46000	250	4500	1350	300		0	52360
Polymer #2	Avg. rate = 620 lb/day, Note A.	3000	210	56.5	45200	300	5400	1620	300		0	52730
Rapid mix	Four tanks, total volume = 2566 cu ft, G = 750 sec-1, one-third time.	167000	11690			180	3240	972	200		0	16102
Flocculation	Eight tanks, total volume = 233,000 cu ft, G = 50 sec-1, one-third time.	100000	7000			150	2700	810	4000		0	14510
Filters (high rate)			0				0	0			0	0
Structures	Forty-eight filter beds, 63552 sq ft total area		0			20950	377100	113130	128000		0	618230
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft	1970000	137900			840	15120	4536	29000		0	186556
Backwash reservoir	Volume = 250,000 gal.		0			10	180	54	200		0	434
Spent backwash basin/thickener	Volume = 57 million gallons, one dredge, operating half time		0			1300	23400	0	2000	1600	1120	26520
Dedicated land disposal	Area = 335 acres, two subsurface sludge injection vehicles operating half time		0			2600	46800	14040	3000	1100	770	64610
Monitoring	People = 3		0			6240	112320	33696	10000		0	156016
Operations bldg.	Area = 10,000 sq ft, includes offices, laboratory, maintenance.	1000000	70000				0	0	20000		0	90000
Miscellaneous			0			0	0	0			0	0
		3268000	228760	3840	562700	37020	666360	192888	231500	336700	235690	2117898

Notes

A. Chemicals, dollars/ton	
FeCl3 (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel, dollars/gal	0.7
E. Admin. & supp matl,	

TABLE 3 : OPERATING AND MAINTENANCE COSTS – S-7 LOW RATE DIRECT FILTERS

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
			0			0	0	0	0	0	0	0
			0				0	0			0	0
			0				0	0			0	0
Feed pumping	Average flow 110 mgd, 20 ft TDH		0			3000	54000	16200	27000	247000	172900	270100
			0				0	0			0	0
			0				0	0			0	0
Chemical delivery			0				0	0			0	0
FeCl3	Avg. rate = 633 lb/hr, pure, Note A.	20000	1400	2761	345125	400	7200	2160	400		0	356285
Polymer #1	Avg. rate = 92 lb/day, Note A.	3000	210	8.5	34000	250	4500	1350	300		0	40360
Polymer #2	Avg. rate = 458 lb/day, Note A.	3000	210	41.5	33200	300	5400	1620	300		0	40730
			0				0	0			0	0
Rapid mix	One tank, total volume = 680 cu ft, G = 750 sec−1, runs 71% of time	50000	3500			355	6390	1917	320		0	12127
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Flocculation	Two tanks, total volume = 61000 cu ft, G = 50 sec−1, runs 71% of time	25000	1750			210	3780	1134	2600		0	9264
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Filters (low rate)			0				0	0			0	0
Structures	Twenty filter beds, 27580 sq ft total area, 71% of time		0			19500	351000	105300	92000		0	548300
			0				0	0			0	0
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft	470000	32900			450	8100	2430	15500		0	58930
			0				0	0			0	0
			0				0	0			0	0
Backwash reservoir	Volume = 70000 gal.		0			5	90	27	100		0	217
			0				0	0			0	0
Spent backwash basin/thickener	Volume = 27 million gallons, one dredge, operating half time		0			1300	23400	7020	1000	750	525	31945
			0				0	0			0	0
			0				0	0			0	0
Dedicated land disposal	Area = 120 acres, one subsurface sludge injection vehicle operating half time		0			1300	23400	7020	1500	550	385	32305
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Monitoring	People = 3		0			6240	112320	33696	10000		0	156016
			0				0	0			0	0
Operations bldg.	Area = 10000 sq ft, includes offices, laboratory, and maintenance	1000000	70000				0	0	20000		0	90000
			0				0	0			0	0
			0				0	0			0	0
Miscellaneous			0			0	0	0			0	0
			0				0	0			0	0
		1571000	109970	2811	412325	33310	599580	179874	171020	248300	173810	1646579

Notes

A. Chemicals, dollars/ton	
FeCl3 (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel, dollars/gal	0.7

TABLE 4 : OPERATING AND MAINTENANCE COSTS – S-7 HIGH RATE DIRECT FILTERS

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
			0			0	0	0	0	0	0	0
Feed pumping	Average flow 110 mgd, 20 ft TDH		0			3000	54000	16200	27000	247000	172900	270100
Chemical delivery			0				0	0			0	0
FeCl3	Avg. rate = 633 lb/hr, pure, Note A.	20000	1400	2761	345125	400	7200	2160	400		0	356285
Polymer #1	Avg. rate = 92 lb/day, Note A.	3000	210	8.5	34000	250	4500	1350	300		0	40360
Polymer #2	Avg. rate = 458 lb/day, Note A.	3000	210	41.5	33200	300	5400	1620	300		0	40730
Rapid mix	One tank, total volume = 680 cu ft, G = 750 sec-1, runs 71% of time	50000	3500			355	6390	1917	300		0	12107
Flocculation	Two tanks, total volume = 61000 cu ft, G = 50 sec-1, runs 71% of time	25000	1750			210	3780	1134	2600		0	9264
Filters (low rate) Structures	Twelve filter beds, 15636 sq ft total area, 71 % time		0			11100	199800	59940	75000		0	334740
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft	470000	32900			450	8100	2430	15500		0	58930
Backwash reservoir	Volume = 70000 gal.		0			5	90	27	100		0	217
Spent backwash basin/thickener	Volume = 27 million gallons, one dredge, operating half time		0			1300	23400	7020	1000	750	525	31945
Dedicated land disposal	Area = 120 acres, one subsurface sludge injection vehicle operating half time		0			1300	23400	7020	1500	550	385	32305
Monitoring	People = 3		0				0	0			0	0
Operations bldg.	Area = 10000 sq ft, includes offices, laboratory, and maintenance	1000000	70000			6240	112320	33696	10000		0	156016
Miscellaneous			0			0	0	0	20000		0	90000
		1571000	109870	2811	412325	24910	448380	134514	154000	248300	173810	1432999

Notes

A. Chemicals, dollars/ton	
FeCl3 (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel dollars/gal	

TABLE 5 . OPERATING AND MAINTENANCE COSTS - S-5A CHEMICAL TREATMENT WITH WETLANDS

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Feed pumping	Average flow 115 mgd, 20 ft TDH		0			3100	55800	18740	28000	257000	179900	280440
			0				0	0			0	0
			0				0	0			0	0
Chemical delivery			0				0	0			0	0
FeCl3	Avg rate = 1158 lb/hr, pure, Note A.	30000	2100	5075	834375	750	13500	4050	700		0	654725
Polymer #1	Avg rate = 100 lb/day, Note A.	3000	300	17.5	70000	300	5400	1620	300		0	77820
Polymer #2	Avg rate = zero lb/day, Note A.		0		0		0	0			0	0
			0				0	0			0	0
Rapid mix	Four tanks, total volume = 1785 cu ft, G = 750 sec-1, one-third time.	100000	7000			170	3080	918	200		0	11178
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Flocculation	Sixteen tanks, total volume = 1580000 cu ft, G = 50 sec-1, one-third time.	830000	58100			300	5400	1620	13000		0	78120
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Sedimentation basins	Sixteen 3.9 acre basins in parallel, operating 1/3 of the time. Dredging occurring half time.		0			4116	74124	22237.2	21000	1600	1120	115481.2
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Stormwater treatment areas	Area = 5680 active acres		0			10300	185400	85620	113800		0	354820
			0				0	0			0	0
			0				0	0			0	0
Discharge pumping	Average flow 192 mgd, 10 ft TDH		0			5000	90000	27000	48000	216100	150570	315570
			0				0	0			0	0
Dedicated land disposal	Area = 331 acres, two subsurface sludge injection vehicles operating half time		0			2600	46800	14040	3000	1100	770	64810
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Monitoring	BTA (44857 hrs, analyt. = $282,000) Chem. tr (6240 hrs, anal = $10,000)		0			55200	993600	298080	272400		0	1584080
			0				0	0			0	0
			0				0	0			0	0
Operations bldg	Area = 10000 sq ft, includes offices, laboratory, and maintenance	1000000	70000				0	0	20000		0	90000
			0				0	0			0	0
			0				0	0			0	0
Miscellaneous			0			0	0	0			0	0
			0				0	0			0	0
		1963000	137500	5092.5	704375	81836	1473084	441825.2	520200	474600	332360	3609444.2

Notes

A Chemicals, dollars/ton	
FeCl3 (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B Power, dollars/kwh	0.07
C Labor, dollars/hour, including benefits	18
D Fuel dollars/gal	0.7

TABLE 6 : OPERATING AND MAINTENANCE COSTS – S–7 CHEMICAL TREATMENT

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
Feed pumping	Average flow 130 mgd, 20 ft TDH		0			3400	61200	18360	33000	291300	203910	316470
Chemical delivery			0				0	0			0	0
FeCl3	Avg. rate = 1315 lb/hr, pure, Note A	35000	2450	5765	720625	900	16200	4860	800		0	744935
Polymer #1	Avg. rate = 110 lb/day, Note A	3000	300	20	80000	300	5400	1620	300		0	87620
Polymer #2	Avg. rate = zero lb/day, Note A		0		0		0	0			0	0
Rapid mix	Three tanks, total volume = 1325 cu ft, G = 750 sec−1, 71 % time	90000	6300			390	7020	2106	280		0	15706
Flocculation	Twelve tanks, total volume = 1190000 cu ft, G = 50 sec−1, 71% time	622000	43540			572	10296	3088.8	21000		0	77924.8
Sedimentation basins	Twelve 3.9 acre basins in parallel, operating 71% of the time. Dredging occurring half time		0			8861	159498	47849.4	34000	1300	910	242257.4
Dedicated land disposal	Area = 346 acres, two subsurface sludge injection vehicles operating half time		0			2600	46800	14040	2600	1000	700	64140
Monitoring	People = 3		0			6240	112320	33696	10000		0	156016
Operations bldg.	Area = 10000 sq ft, includes offices, laboratory, and maintenance	1000000	70000				0	0	20000		0	90000
Miscellaneous			0			0	0	0			0	0
		1750000	122590	5765	800625	23263	418734	125620.2	121980	293600	205520	1795069.2

Notes

A. Chemicals, dollars/ton	
FeCl3 (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel, dollars/gal	0.7

TABLE 7 : OPERATING AND MAINTENANCE COSTS – S–5A STA

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
Wetlands	Area = 11200 acres active area					20300	365400	109620	56000	10000	7000	538020
Monitoring	Cost = $231000/1000 acre year					88451	1592118	477635.4	517000			2586753.4
Operations bldg.	Area = 10,000 sq ft, includes offices, laboratory, maintenance.	1000000	70000						20000			90000
Effluent pumping	Average flow = 192 mgd, TDH = 10 ft					5000	90000	27000	48000	215000	150500	315500
Miscellaneous												
		1000000	70000	0	0	113751	2047518	614255.4	641000	225000	157500	3530273.4

Notes

A. Chemicals, dollars/ton
FeCl3 (pure) = 124
Polymer #1 = 4000
Polymer #2 = 800

B. Power, dollars/kwh 0.07

C. Labor, dollars/hour, including benefits 18

D. Fuel, dollars/gal 0.7

E. Admin. & supp. mult. 0.3

TABLE 8 : OPERATING AND MAINTENANCE COSTS – S-7 STA

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
Influent pumping	Average flow = 210 mgd, 10 ft TDH		0			5200	93600	28080	52000	235000	164500	338180
Wetlands	Area = 5680 acres active area		0				0	0			0	0
			0			10300	185400	55620	28400	10000	7000	276420
Monitoring	Cost = $231000/1000 acre year		0				0	0			0	0
			0			44900	808200	242460	262400		0	1313060
Operations bldg	Area = 10,000 sq ft, includes offices, laboratory, maintenance		0									
		1000000	70000				0	0			0	0
			0				0	0	20000		0	90000
Miscellaneous			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
											0	0
		1000000	70000	0	0	60400	1087200	326160	362800	245000	171500	2017660

Notes

A. Chemicals, dollars/ton	
$FeCl_3$ (pure) =	125
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel, dollars/gal	0.7
E. Admin. & supp. mult.	0.3

TABLE 7 : OPERATING AND MAINTENANCE COSTS – S–5A STA

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel Dollars	Total dollars
			0				0	0			0	0
Wetlands	Area = 11200 acres active area		0			20300	365400	109620	56000	10000	7000	538020
			0				0	0			0	0
Monitoring	Cost = $231000/1000 acre.year		0			88451	1592118	477635.4	517000		0	2586753.4
			0				0	0			0	0
Operations bldg.	Area = 10,000 sq ft, includes offices, laboratory, maintenance.	1000000	70000				0	0	20000		0	90000
			0				0	0			0	0
			0				0	0			0	0
Effluent pumping	Average flow = 192 mgd, TDH = 10 ft		0			5000	90000	27000	48000	215000	150500	315500
			0				0	0			0	0
			0				0	0			0	0
Miscellaneous			0				0	0			0	0
		1000000	70000	0	0	113751	2047518	614255.4	641000	225000	157500	3530273.4

Notes

A. Chemicals, dollars/ton	
FeCl3 (pure) =	124
Polymer #1 =	4000
Polymer #2 =	800
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel, dollars/gal	0.7
E. Admin. & supp. mult.	0.3